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SYMPOSIUM: PLANETARY RADIO ASTRONOMY

AN ACCOUNT OF THE DISCOVERY OF JUPITER AS A RADIO SOURCE

BY K. L. FRANKLIN

Vannevar Bush has said that there is no more thrilling experience for a man than to be able to state that he has learned something no other person in the world has ever known before him. This experience is not rare in the life of a successful research scientist, as witness the papers published in our journals and to be presented to this meeting in the next few days. Often, such an experience comes gradually and almost without one's awareness; but occasionally a discovery is made with dramatic swiftness which leaves the participants in a state of excitement. I have been lucky enough to be included in such an event, and I have been asked to recount this anecdote as an introduction to this symposium.

When I arrived at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington as a Research Fellow, on September 1, 1954, I was introduced to the world's largest (and least conspicuous, as Bernard Burke remarked) radio telescope. This Mills Cross, described in the literature, had been constructed during June and was being operated by Burke. Dr. M. A. Tuve, Director of D.T.M., suggested that I work with Dr. Burke on the 22.2 Mc Sky Survey for which the Mills Cross was built. I had to learn many things that I still find mysterious, and it was interesting to participate in the development of some of the tools of radio astronomy.

The receiver and auxiliary equipment were constantly being improved during the first few months of 1955. In order to discern the results of

each improvement, we left the pencil beam (about 2.5° wide to half-power points) directed to the declination of the Crab Nebula, the strong radio source in Taurus, and compared records obtained before and after each modification. We decided to scan the region near the Crab Nebula in order to build up a two-dimensional picture of this part of the sky. Arbitrarily, we directed the beam southward by about 1° at three- or four-week intervals.

The records themselves showed the characteristic hump as the Crab Nebula passed through the pencil beam. This was followed by a smaller hump, lasting the same 15^m , attributed to IC443. At times the records exhibited a feature characteristic of interference, occurring some time later than the passage of the two known sources. This intermittent feature was curious, and I recall saying once that we would have to investigate the origin of that interference some day. We joked that it was probably due to the faulty ignition of some farm hand returning from a date.

We decided to present the material we had to the Princeton meetings of the A.A.S. in April 1955. Accordingly, Burke assembled all the records of the Taurus region for the first three months of 1955 in preparation for the reductions. He temporarily laid aside those with interference on them, and concentrated on the two-thirds remaining. Burke noticed a gentle rise and fall that was usually present some time after IC443 had crossed the meridian. To investigate this feature more fully, he examined the records con-

taining interference, finding that the interference usually occurred at the time the rise-and-fall was supposed to be present. He was then startled to find that the interference always occurred at almost the same sidereal time. A strange rural romance this was turning out to be! As spring drew nearer, our swain was returning home earlier and earlier, each evening.

Since the source of the "interference" was clearly attached to the sky, we immediately went to an atlas to find anything that might be obvious. A peculiar galactic cluster and an interesting planetary nebula were candidates, but they were ruled out when we noticed that this strange source was not always at the same right ascension. It appeared to drift westward, slightly, over the three-month interval, so that in March the two interesting objects were not in the beam at the time of the recorded event.

The late Howard Tatel, a man of many parts, was present in the laboratory, working on some of his seismic records. He and Dr. Tuve were the principal investigators at D.T.M. of the distribution of hydrogen in the galaxy. At the suggestion of Dr. Richard Roberts of D.T.M., Tatel had looked at Jupiter a few nights before with the *H*-line equipment, and found nothing. Having this in mind, he somewhat facetiously suggested to Burke and me that our source might be Jupiter. We were amused at the preposterous nature of this remark, and for an argument against it I looked up Jupiter's position in the American Ephemeris and Nautical Almanac. I was surprised to find that Jupiter was just about in the right place, and so was Uranus. Here was something which needed clearing up. Unfortunately, we had no more time that afternoon to work on it, because we had to go out to the Mills Cross and work until evening. As twilight came and went, we were delighted by a fine, clear sky. Burke asked me what one exceptionally bright object was, almost on the meridian. We had a good laugh when I told him it was Jupiter.

The next morning, I plotted the right ascensions as a function of the date for the points of beginning and ending of each recorded event, and drew a smooth curve through the points locating each phenomenon. I then placed the right ascensions of the two interesting galactic objects on the plot, and followed this with the positions of Uranus throughout the observing interval. The objects of fixed right ascension were represented by horizontal straight lines, and Uranus exhibited the slow westward change due to its retrograde

motion at the time. The galactic objects nearly fit within the region of the plot bounded by the two similar curves representing the limits of the recorded events, but these objects could not represent the change of right ascension with date. Uranus, while apparently within the beam early in January, did not drift westward nearly as rapidly as the events required. At this point in the growth of the diagram, I began to plot the right ascensions of Jupiter. As I plotted each point, Burke, who was watching over my left shoulder, would utter a gasp of amazement. Each point appeared right between the boundary lines representing the beginning and end of each event! The meaning was exquisitely clear: these events were recorded only when the planet Jupiter was in the confines of the narrow principal beam of the Mills Cross. Not only did this source have the same direction in space as Jupiter, but it also exhibited the same change of direction as Jupiter did during its retrograde loop of 1955. No other object could satisfy the data: the source of the intermittent radiation was definitely associated with Jupiter!

Such is the actual story of this very unexpected discovery. The events which followed are essentially anti-climatic, but it may prove amusing to recount one other personal part in the story of Radio Jupiter. After the announcement of the discovery was made at Princeton, the National Broadcasting Company requested that we make a tape recording of this noise which they could put on their first Monitor program. They supplied the recorder and we hooked it into the equipment. Only fifteen minutes each day were possible in which we could receive any radiation from Jupiter. On Easter Sunday, there was a fine event recorded on the paper tape, but the magnetic recorder was not operating until the next day. Each afternoon, I raced the twenty miles out to the field in order to be on hand when and if Jupiter should be active. Roughly three weeks later the next event occurred on a Friday afternoon. Until I played the tape for everyone at D.T.M. on Monday morning, I was the only one in the world who had heard Jupiter and who knew it.

Naturally, we wrote to our colleagues in other parts of the world. C. A. Shain, in Australia, immediately began observations which confirmed our identification, and he searched his old records for possible predisccovery observations. It turned out that he had actually received noise from Jupiter in 1950, but had attributed

it to interference. Those prediscovers records have proved of great value as early-epoch data, and have been discussed in the literature.

Our identification of Jupiter as a radio source is not based directly on reasoning, but more on luck. (Professor Herbert Dingle once described this as the real scientific method, in a talk before the National Science Foundation.) We were led into it by the nature of our equipment: a very narrow pencil beam. Shain had a broad beam which was suited to his needs, but which enabled him to overlook the celestial source of "interference" appearing on his records. Another curious bit of chance shows up when we reviewed our arbitrary southward redirection of the pencil beam: we were inadvertently following Jupiter southward as well as if we had planned it! (Incidentally, we never did learn the cause of the rise and fall which started all this.)

A further favorable attribute of much of the radiation from Jupiter is its intensity. It can be very powerful, even more intense than Cassiopeia A, the strongest source in the sky at this frequency, around 20 Mc. Only the active sun is apparently stronger, at times. Thus, when Jupiter is acting well, it is not difficult to observe, as radio sources go. It is well, however, to recall that any radio source is very weak compared to the general amount of noise entering the antenna system, and even sometimes produced in the equipment itself. As a reminder to the prospective observer of extraterrestrial radio noise, I shall conclude by offering the following motto for radio astronomers (with apologies to Gertrude Stein): Signals in the grass, alas!

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RADIO FREQUENCY EMISSION FROM THE PLANET JUPITER

BY THOMAS D. CARR

Until 1955, the only source of observational information on the strange phenomena occurring in the atmosphere of Jupiter was the light from the tops of the Jovian clouds. However, the discovery by Burke and Franklin (1955) that Jupiter is sporadically emitting intense bursts of energy in the radio spectrum in the vicinity of 22 Mc provided a new means for gaining knowledge about the planet and its atmosphere. The cause of the radiation is not yet known; nevertheless, investigation of it by the several participating research groups has already yielded considerable information about the environment in which it originates.

Although the radio noise burst occurrences are unpredictable, statistical analysis of data recorded over a period of several months indicates an unmistakable correlation with the rotation of the planet. Immediately after learning of the discovery of Burke and Franklin, Shain (1956) in Australia re-examined a series of records he had made four years earlier at 18 Mc, and found on them many instances of Jupiter noise activity. These events had previously been mistaken for terrestrial interference. Shain demonstrated that there is a striking correlation of occurrence probability with the longitude of the central meridian of Jupiter's visible disc provided a

rotational period is assumed which lies within about 30 seconds or so of that of System II ($9^h55^m40^s.6$). There was no correlation if the System I period ($9^h50^m30^s$) was assumed. His analysis showed that occurrences were largely limited to a band of central meridian longitudes less than 180° wide. This indicates, he pointed out, not only that the radio sources are concentrated within a certain area but also that the planet is surrounded by an ionosphere. Thus, escape is possible only for the cone of rays incident on the ionosphere at less than the critical angle.

The next logical step was to determine whether or not the principal noise source remains fixed at the same longitude from one year to the next. Unfortunately, terrestrial ionospheric effects have thus far limited reliable radio observations of Jupiter to the two or three months of the year during which meridian transit occurs between about 2 A.M. local time and sunrise. The rotational period established from the data obtained during a single apparition is usually relatively inaccurate. However, with data from three or more apparitions, one can determine with considerable accuracy whether or not the rotational period of the principal noise source was constant. Gallet (1957) of the National Bureau of Stand-

ards was the first to do this. He announced that from an analysis of Shain's 1951 data and his own of 1956 and 1957 he had deduced that the noise sources on the planet were rotating at a constant period about 10 seconds less than that of System II. He concluded that the noise sources must be fixed to the solid surface of Jupiter. Unfortunately, Gallet has not yet published his results.

Shortly afterward, Prof. A. G. Smith and I at the University of Florida obtained some of the 1955 Burke and Franklin data, which with Shain's data of 1951 and our own data of 1957 gave us the required three sets. We found (Carr *et al.* 1958) that the regions of maximum and minimum noise activity appear to be rotating with a constant period of $9^{\text{h}}55^{\text{m}}28^{\text{s}}.8$. We have defined as "System III" the longitude coordinate system which rotates with this period and which coincided with System II at 0^h UT on January 1, 1957. We have since obtained data from two other apparitions—the 1955–56 data of Gardner and Shain (1958) and our own of early 1958. This additional data substantiates our System III rotational period remarkably well. The constancy of location of the principal noise source for the five sets of data spanning a period of eight years indeed seems indicative that the active region is anchored to a solid surface rather than drifting about in a fluid atmosphere.

There appears to be a strong inverse correlation of Jupiter noise activity with sunspot activity. The correlation has not yet been demonstrated quantitatively, however.

We at the University of Florida observed (Carr *et al.* 1958) an unmistakable periodicity of about eight days in the Jupiter noise activity early in 1957. We originally suggested that it might arise from tides in Jupiter's ionosphere due to one of its satellites. However, Douglas and Smith of Yale have pointed out that it is more likely to be a stroboscopic effect—every seven or eight days the active area was facing the earth during our nightly three-hour observation period. Further analysis will be made in an attempt to settle the matter.

Franklin and Burke observed in 1956 that the radiation from Jupiter is elliptically polarized, predominately in the right-hand sense. This is good evidence that Jupiter has both an ionosphere and a magnetic field.

We constructed a 22.2 Mc crossed-yagi polarimeter at the University of Florida in order to study this effect further. The polarimeter per-

mitted the determination of the axial ratio and sense of the polarization ellipse for every burst. Data were obtained on four nights in the spring of 1958, and many bursts were observed each night. In every case, without exception, the radiation was right-handed elliptically polarized. However, the axial ratio varied in apparently random fashion, occasionally indicating circular polarization. Our calculations indicated that the degree of polarization observed could not have arisen in the terrestrial ionosphere.

If in addition to the measured axial ratio of the polarization ellipse, the magnetic latitude of the source and the ionospheric critical frequency are known, the magnetic field intensity on Jupiter can be calculated by means of the Appleton formula. After making seemingly plausible guesses of 20°S for the latitude and 17 Mc for the critical frequency, we arrived at seven gauss for the magnetic field intensity in Jupiter's ionosphere.

Radiation from Jupiter has been reported by the various observers from 14 to about 30 Mc or a bit higher. Activity above 20 Mc drops off rapidly with increasing frequency. Gardner and Shain (1958) have reported that there is less activity at 14 than at 19.6 Mc, indicating a maximum in the vicinity of 19 Mc. This is close to the approximate critical frequency as deduced from the width of the active longitude sector (Carr *et al.* 1958). The spectrum below about 14 Mc has thus far been inaccessible because of the increasing opacity of the terrestrial ionosphere with decreasing frequency.

A distinction must be made between the average spectrum and the spectrum of the individual burst. Single bursts appear to contain frequencies of only about 0.5 Mc bandwidth. Although at a given time there may be activity over a frequency band considerably in excess of this, correlation of bursts more widely separated than 0.5 Mc is apparently very slight.

The first suggestion advanced to account for the radiation from Jupiter was that it results from atmospheric discharges. However, the noise is entirely different in character from terrestrial radio static. A more widely accepted theory is that the radiation results from plasma oscillations in Jupiter's ionosphere. Gallet maintains that the plasma oscillations are excited by shock waves arising from volcanic explosions in Jupiter's crust. A well-supported theory will probably not be forthcoming until more complete spectral information is available. Artificial

earth satellites can probably be used to obtain the spectrum below the critical frequency of the terrestrial ionosphere.

During a Jupiter disturbance one hears from the loudspeaker repeated bursts of random noise, each burst lasting from about 1 to 10 seconds. High speed recordings made by Kraus, Gallet, and the University of Florida group also indicate occasional sharp spikes, which tend to appear in groups. The interpretation of these effects could well lead to an explanation of the origin of the noise.

With the support of the National Science Foundation, the University of Florida group is planning to establish an auxiliary planetary radio observatory in Chile in cooperation with the Astronomical Observatory of the University of Chile near Santiago. The declinations of both

Jupiter and Saturn will be much more favorable during the next few years for observation from the southern hemisphere than from the northern. We plan to make simultaneous observations from Florida and Chile frequently in order to evaluate the effects of terrestrial interference and possible effects of the terrestrial ionosphere.

REFERENCES

- Burke, B. F. and Franklin, K. L. 1955, *J. Geophys. Res.* **60**, 213.
 Carr, T. D., Smith, A. G., Pepple, R. and Barrow, C. H. 1958, *Ap. J.* **127**, 274.
 Gallet, R. M. 1957 (May), *Program for URSI-IRE Spring Meeting* (unpublished abstract).
 Gardner, F. F. and Shain, C. A. 1958, *Australian J. Phys.* **11**, 55.
 Shain, C. A. 1956, *Australian J. Phys.* **9**, 61.

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NON-THERMAL SOLAR SYSTEM SOURCES OTHER THAN JUPITER

BY HARLAN J. SMITH

The discovery of strong non-thermal radiation from Jupiter immediately raised the question whether any other sources of non-thermal meter-wave radiation are present in the solar system. The answer is hard to find for several reasons: poor angular resolution at these wave lengths makes the direction of the source difficult to determine; background noises of many kinds, both natural and man-made, are present at these wave lengths most of the time; and finally, the very nature of the signals being sought is uncertain—even should they exist, they may not necessarily resemble Jupiter's.

Under these conditions, general acceptance of a new source requires some relatively unambiguous recognition system. The Mills Cross used for the initial discovery, while highly directive, permits only a few minutes of observation per day on any selected object. The most commonly employed technique for obtaining effective resolution coupled with long observing time is the use of a wide-spaced interferometer, the elements of which are somewhat directive. These elements generate a broad lobe of sensitivity in the sky (for example, the entire celestial equator region from horizon to horizon) which in turn is given a fine structure by the interferometer pattern. Switching the phase of the interferometer at an audio rate discriminates against all sources which

are large with respect to the interferometer pattern; incorporation of phase-sensitive detection requires noise from celestial point sources to reverse direction in a characteristic sinusoidal pattern on the receiver records.

The solar system includes only a few objects which seem to be worth serious consideration as possible non-thermal sources. The sun, although occasionally the strongest source at these wave lengths, is a separate problem not considered here. Pluto seems unlikely because of its distance, size, and surface temperature. Objects without atmospheres, including Mercury, asteroids and most of the satellites, are also highly unlikely as sources. No information is available for Mars and Neptune. Uranus was close to Jupiter during the original Carnegie period of discovery (Burke and Franklin 1955) and was not an active source during this period. Since at least six sets of observers (Sydney, Carnegie Institution at Washington, Ohio State, Boulder, Florida, and Yale) have failed to report any characteristic noise which might be associated with Mars, Neptune or Uranus, it seems reasonable to conclude that these planets are either highly infrequent emitters or that their signal strengths at the earth are normally much weaker than $10^{-21} \text{ W cm}^{-2} \text{ cps}^{-1}$. Three possible objects are left: comets, Venus and Saturn.

In the spring of 1957 Comet Arend-Roland (1956h) offered unusually favorable circumstances. Kraus (1958a) reported picking up at 27.6 Mc a source which may have been related to the comet. His antenna consisted of an ingenious set of rotating helices, which swept a fan beam 12° in right ascension and 60° in declination from about two hours east to about two hours west once every two minutes; side lobes, 5 db down, fell three hours on each side of the main lobe. A source was observed in the morning hours, weakening before noon, suggesting its presence in the east side-lobe, with increasing ionospheric absorption normally preventing its observation at noon and later in the day. During the period of observation (March 10 to May 17, 1957) the source in question deviated only slightly from sidereal rate of change of transit time. The comet itself, with respect to the east side-lobe, had only two significant deviations from sidereal transit rate, in late March and around April 15 to 20. Both deviations seemed to be followed rather closely by the source. The radio intensity of this source also followed roughly the predicted magnitudes of the comet, with intensities reaching about $5 \times 10^{-22} \text{ w cm}^{-2} \text{ cps}^{-1}$.

The other planetary observers, working at lower frequencies (18 to 21 Mc), failed to report the comet. In most, if not all cases, their equipment was relatively insensitive compared to Kraus' at the high declinations corresponding to the comet when in the evening sky, and their lower frequencies led to more serious troubles with absorption and interference when it was near the sun. Whitfield and Högbom (1957) at Cambridge, during a period coincident with that of Kraus, observed at 38 and 81 Mc using five different instruments including two interferometers. They found no trace of the comet down to limiting intensities 0.25 and $0.5 \times 10^{-24} \text{ w cm}^{-2} \text{ cps}^{-1}$ at 38 and 81 Mc, respectively. These clear-cut upper limits, while disappointing in not revealing the comet, do not completely disprove Kraus' observations. If the spectral energy distribution falls off steeply enough, these results could still be reconciled. A factor of about 10^{-2} is needed between 27 and 38 Mc. Although the data are uncertain, it seems that with Jupiter the factor is at least 10^{-1} over the same frequency range.

In 1956, using a conventional interferometer at 26.7 Mc, Kraus (1956) reported finding intense pure noise signals when Venus was drifting through the main antenna beam. The noises

somewhat resembled records of Jupiter, consisting of randomly spaced spikes of short duration, one second or less. A second type of signal was occasionally observed, characterized by longer duration of pulses, several megacycles bandwidth, occurrence with random spacing, and modulation at low audio-frequency rates. Several of these "Class II" pulses seemed to be accompanied with echoes having approximately the lunar travel time. The probability of this explanation is reduced by the requirement of parabolic focusing areas on the moon several miles in diameter, and the difficulty that the echo delays are 0.25 sec too long. It is hard to imagine any mechanism leading to so large a delay over the short space between the earth and the moon. Kraus also pointed out a 13-day periodicity in the data attributed to Venus which, if interpreted as a beat-frequency between the rotation periods of Venus and earth, suggests a period of about 22 hours for Venus. Optical evidence seems adequate to rule out such rapid rotation. In summary, the evidence for Venus rests primarily on the degree to which the noises attributed to Venus fit the interferometer pattern. The relative coarseness of the pattern employed, the lack of phase-sensitive detection, the confused nature of the noise, and the presence of the sun nearby in the sky all tend to make such interpretation difficult. The published cases are suggestive (see Kraus 1956, p. 103 and 1958b, p. 273), but not completely convincing. Venus has been looked for by other observers at lower frequencies (18 to 23 Mc) without success.

Saturn's extremely close resemblance to Jupiter in physical properties makes it a tempting planet for investigation. Using steerable Yagis as interferometer elements, we have been able at Yale to concentrate our directivity on Saturn during the periods when it was best observable in the late spring of 1957 and 1958. During the first year (Smith and Douglas 1957), data were taken at 21.1 Mc with an interferometer having one-hour lobes and without phase-sensitive detection. So coarse a system made identifications uncertain. Nevertheless, usable results were obtained on Jupiter by requiring the following conditions for probable identification: 1) The planet had to be in the beam of the Yagis; 2) the interference pattern should not be violated; 3) the noise should not be identified as recognizable interference by the observer on duty. The resulting Jupiter records agreed closely in rotation histogram with those obtained by quite different

methods during the preceding two months by the Florida observers. A dozen rather similar events were noted when Saturn was in the beam of the Yagis, which failed to fit Jupiter in any way. Most of these records showed a somewhat more sustained and less bursty type of noise than is conventionally associated with Jupiter, having durations ranging from half an hour to five or six hours of intermittent activity. An assumed rotation period for Saturn of $10^h 22^m$ would place all of these events except one on the same hemisphere of Saturn.

Extensive changes were made in the receiving equipment to follow up these observations in 1958. Three widely spaced interferometers were employed, two of them with base lines of 960 feet. Two frequencies, 22.2 and 23.0 Mc, were used. However, during April and May only eight significant Jupiter events were recorded, most of them quite weak; from April to July, only two possible Saturn events were noted (Smith and Douglas 1959). Contradicting the reality of Saturn as a source are three main facts: 1) In few cases is the fit of Saturn to the interferometer pattern quite perfect. While ionospheric effects at the low altitude of Saturn are possible, one would prefer completely convincing data; 2) the better equipment has yielded fewer results; 3) there has been no clear-cut confirmation from other observers. The Florida workers (unpublished) have detected by ear about a dozen brief periods of Jupiter-like "swishes" when Saturn was in the beam of their principal antenna. Unfortunately, in several cases where there is overlap

with the Yale records, nothing was recorded by the Yale equipment. Practically all of Yale's possible Saturn events occur when the Florida equipment was not recording; in two instances where comparison with good cases is possible (1957 UT May 8.3 and May 14.2) both receivers seem to be picking up a similar noise of non-Jovian, but possibly atmospheric, type.

In conclusion, Jupiter remains the only positively-established non-thermal solar-system source at meter wave-lengths, apart from the sun itself. Suspicion has been cast on comets, Venus, and Saturn. In each case the observations are not sufficiently clearcut to be convincing. Several observers now have equipment capable of practically certain detection of such sources should they give even a relatively few minutes of strong radiation. But disproof of these objects as sources can only be achieved through a very long program of observations at a number of frequencies, in view of the sporadic nature of such noise storms and their apparently narrow localization in frequency.

REFERENCES

- Burke, B. F. and Franklin, K. L. 1955, *J. Geophys. Res.* **60**, 213.
 Kraus, J. D. 1956, *Nature* **178**, pp. 33, 103, 159, 687.
 —. 1957, *A. J.* **62**, 21.
 —. 1958a, *A. J.* **63**, 55.
 —. 1958b, *Proc. Inst. Radio Engrs.* **46**, 266.
 Smith, H. J. and Douglas, J. N. 1957, *A. J.* **62**, 247.
 —. 1959, *Proc. URSI-IAU Radio Astron. Symp. Paris 1958*, in press.
 Whitfield, G. R. and Högbom, J. 1957, *Nature* **180**, 602.
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PLANETARY RADIATION AT CENTIMETER WAVE LENGTHS

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Thermal radio radiation from the planets is of very low intensity, and it was not until 1956 that Venus, Jupiter, and Mars were observed using the Naval Research Laboratory 50-foot reflector. Even though weak, the radiation collected by the antenna can be calibrated quite accurately by comparison with thermal noise sources. The main uncertainty in the present observations is introduced by the inaccurate knowledge of the effective collecting area of the antenna. Observations of planetary radio radiation are expected to contribute physical data relevant to the lower atmospheres and crusts of the planets. At the present time observations have been made of Venus, Jupiter, Mars, and Saturn.

Venus. Venus was observed near the time of the inferior conjunction of June 1956 using the 50-foot reflector at 3.15 cm (Mayer, McCullough, Sloanaker 1958a, b). The average apparent blackbody temperature decreased from 620°K at about 40 days before conjunction to 560°K near conjunction. Another unpublished group of observations by the same workers, made from 15 to 28 days after the conjunction of January 1958 using the same antenna at 3.4 cm, gave an average apparent blackbody temperature of 518°K . Further observations made at 80 and 81 days after this conjunction using the same antenna at 3.37 cm and the Columbia University maser radiometer (Alsop, Giordmaine, Mayer, and

Townes 1958, 1959), gave an apparent blackbody temperature of 574°K . The probable error on these average values is about 9 per cent, but the relative accuracy for inter-comparison should be somewhat better.

The most striking feature of these observations of Venus near 3 cm is the high apparent blackbody temperature, more than double that attributed to the top of the cloud layer by infrared radiometric observations (Petit and Nicholson 1955, Sinton 1958) and about double the rotational temperature derived from the carbon-dioxide bands by Chamberlain and Kuiper (1956). The radio results probably refer to a region at or beneath the solid surface of Venus. Wildt (1940) had already noted that the surface temperature might be high due to the CO_2 greenhouse effect; his numerical estimate, depending among other assumptions on a large extrapolation of the emissivity of CO_2 as measured in the laboratory, gave a maximum surface temperature value of 408°K . Likewise, Opik (1956) expressed the opinion that the surface temperature of Venus is probably much greater than the observed radiometric values. From these present data the apparent blackbody temperature decreases until sometime after conjunction and then rises again as might be expected for a phase effect. The existence of the minimum point however is dependent on the two days of observation at 80 days past inferior conjunction, and more data are needed to give a proper interpretation.

Venus has also been observed at two other wave lengths. In each case the signal to noise ratio was less than one and the measurement was made by averaging a number of individual observations.

Eleven observations were made at an average of 21 days after the inferior conjunction of 1956 using the 50-foot reflector at 9.4 cm (Mayer *et al* 1958a, b). A point by point averaging of 11 drift scans gave an apparent blackbody temperature of $580 \pm 160^{\circ}\text{K}$ (p.e.).

In January 1958, Gibson and McEwan (1959) made a number of observations of Venus at 0.86 cm using a 10-foot reflector at NRL. A point by point averaging of 15 drift scans gave an apparent blackbody temperature of $410 \pm 160^{\circ}\text{K}$.

The measurement at 9.4 cm tends to confirm the measurements at 3 cm, while the millimeter wave-length result suggests a value somewhat nearer the infrared value. In any case, the centimeter wave-length spectrum of Venus near conjunction seems very close to that of a blackbody with temperature about 550°K .

Jupiter. A number of drift scans through the position of Jupiter were made during May 1956 and during March 1957 using the 50-foot reflector at 3.15 cm (Mayer, McCullough, Sloanaker 1958b, c). In both cases the signal to noise ratio was less than one and a number of observations were averaged. A point by point average of 29 drift scans obtained in 1956 gave an apparent blackbody temperature for Jupiter of $140 \pm 38^{\circ}\text{K}$. A point by point average of 45 drift scans obtained in 1957 using an improved method gave an apparent blackbody temperature for Jupiter of $145 \pm 18^{\circ}\text{K}$.

Also in 1957, Drake and Ewen (1958) observed Jupiter at 3.75 cm using a 28-foot reflector. They reported an apparent blackbody temperature slightly greater than 200°K but they estimate that their results may be in error by a factor of two.

This past summer Jupiter was observed using the Columbia University maser and the NRL 50-foot reflector (Alsop *et al.* 1958, 1959). With this apparatus it was possible to observe Jupiter on single scans using a 5 second output time constant, and each of the single scans was approximately equivalent in signal to noise ratio to the average of 45 scans obtained the preceding spring. A preliminary average of some of the observations of this sort gave an apparent blackbody temperature for Jupiter of $165 \pm 17^{\circ}\text{K}$. No variation in apparent temperature with rotation of Jupiter was apparent.

Also this past summer R. M. Sloanaker has used the new NRL 84-foot reflector to observe Jupiter at 10.3 cm (McClain and Sloanaker 1959). He finds that the apparent blackbody temperature of Jupiter is very high at this wave length and varies over a range of about 2 to 1. Preliminary results give 580°K for the average of a number of observations which varied individually from about 400 to 900°K . First attempts to correlate the variations in temperature with the rotation of Jupiter were suggestive but not conclusive.

On the basis of the present observations, there is apparently a great change in the emission of radio waves from Jupiter between 3 cm and 10 cm. This can probably be explained by a temperature gradient with depth in the atmosphere along with some large scale turbulence, but there is also the possibility of non-thermal emission. Further observations over a range of wave lengths should indicate the answer.

Mars. Mars was observed at the favorable opposition of 1956 again using the 50-foot reflector at 3.15 cm (Mayer *et al.* 1958b, c). The point by point average of 71 drift scans gave an apparent blackbody temperature for Mars of $218 \pm 50^\circ\text{K}$. The high probable error was largely due to antenna pointing uncertainty.

Saturn. Drake and Ewen (1958) also reported the detection of Saturn at 3.75 cm using the same apparatus as they used for Jupiter. The change in antenna temperature due to Saturn was only 0.04°K .

The measurements of thermal radio radiation from planets have been restricted in scope by the limitations of apparatus sensitivity. Nevertheless, the present results for the more intense planets, Venus and Jupiter, demonstrate the value of such observations in providing previously unobtainable data. Fortunately, a great extension of these observations should be possible with the more sensitive radiometers and larger reflectors now under test and construction. Within a few years it should be possible to ob-

serve Venus and Jupiter from millimeter to about one meter wave-lengths. Mars, Saturn, and Mercury should be observable over about half this range of wave lengths and Uranus and Neptune should be detectable.

REFERENCES

- Alsop, L. E., Giordmaine, J. A., Mayer, C. H. and Townes, C. H. 1958, *A. J.* **63**, 301.
 —. 1959, *Proc. URSI-IAU Radio Astron. Symp. Paris 1958*, in press.
 Chamberlain, J. W. and Kuiper, G. P. 1956, *Ap. J.* **124**, 399.
 Drake, F. D. and Ewen, H. I. 1958, *Proc. Inst. Radio Engrs.* **46**, 53.
 Gibson, J. E. and McEwan, R. J. 1959, *Proc. URSI-IAU Radio Astron. Symp. Paris 1958*, in press.
 Mayer, C. H., McCullough, T. P. and Sloanaker, R. M. 1958a, *Ap. J.* **127**, 1.
 —. 1958b, *Proc. Inst. Radio Engrs.* **46**, 260.
 —. 1958c, *Ap. J.* **127**, 11.
 McClain, E. F. and Sloanaker, R. M. 1959, *Proc. URSI-IAU Radio Astron. Symp. Paris 1958*, in press.
 Öpik, E. J. 1956, *Irish A. J.* **4**, 2.
 Petit, E. and Nicholson, S. B. 1955, *Pub. A. S. P.* **67**, 293.
 Sinton, W. M. 1958, *A. S. P. Leaflet* No. 345.
 Wildt, R. 1940, *Ap. J.* **91**, 266.

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ADDRESS: THE UTILIZATION OF ARTIFICIAL EARTH SATELLITES FOR ASTRONOMICAL RESEARCH

By L. H. ALLER

Many years ago Henry Norris Russell remarked that all good astronomers go to the moon after they die so that they can see the heavens freed from the complications produced by the earth's atmosphere. Since astronomy is an observational science we have to rely on what the stars choose to tell us; we cannot perform experiments on them as do the physicists and chemists upon the objects of their study. The earth's atmosphere puts a severe limitation on what observations the astronomer can make since it transmits but a relatively narrow window of the entire electromagnetic spectrum. One of these windows falls in the optical region between 0.29 micron and about 3 microns. There is also a radio frequency window extending between wave lengths of about 8 millimeters down to about 30 meters. The excluded spectral region includes the astrophysically most interesting portion of the ultraviolet wherein fall the hydrogen Lyman lines and continuum and the resonance transitions of the other most important elements.

Also excluded is the region of the soft x-rays which are produced in highly excited regions such as the solar corona. There is another less obvious complication produced by the earth's atmosphere: this is the general night sky background or "permanent aurora," as it is sometimes called. It limits the surface brightness which we can reach with our best telescopes and longest exposures. Whereas the first emphasis in extra-terrestrial astronomical observations will be on a rapid reconnaissance in the heretofore excluded spectral regions, eventually a large telescope on the moon or a suitable space station will be used to study distant galaxies freed from the annoyance of the sky brightness.

The possibility of exploring the ultraviolet x-ray region of the spectrum of the sun, stars, and the nebulae offers the most engaging problems to the astrophysicist. Consider first some of the problems posed by the sun. It has been known for many years that the occurrence of a sudden ionospheric disturbance (S.I.D.) is cor-

related with the appearance of a solar flare in the vicinity of a sunspot group, but the correlation is not so precise that we can be sure that an S.I.D. will be associated with any particular flare. Indeed, the visible flare appears to be only a symptom of some mechanism, probably hydro-magnetic in character, that liberates large amounts of energy very suddenly. The energy relevant to the production of an S.I.D. must be released in the far ultraviolet and soft x-ray region, and hence can be studied only by devices flown above the earth's atmosphere. Heretofore our information has been obtained only slowly and painfully by rockets fired above the earth's atmosphere. Outstanding contributions have been made by H. Friedman and his group, by Tousey and his associates at the Naval Research Laboratory, and by William A. Rense at the University of Colorado. These experiments have revealed the general character of the ultraviolet spectrum of the sun, and they have shown that high energy x-rays, i.e., those with wave lengths less than 8 Å, provide a good index of solar activity. Friedman and his associates find that there is a good correlation between the flares and radio fadeouts on the one hand and solar x-rays on the other. Furthermore, the intensity of these x-rays depends upon the importance of the flare. Elwert investigated the x-ray emission from the sun theoretically and demonstrated that the enhancement of the high energy x-rays probably comes from local regions where the temperature may reach 6 or 8 million degrees. Rocket observations give us only momentary snapshots of the state of the solar corona and chromosphere, and for a thorough understanding of this phenomenon a continuous patrol is needed.

The ultraviolet spectrum of the sun offers a number of challenging problems. The spectral region between 700 Å and 100 Å is particularly difficult to study because the transmission of the earth's atmosphere remains poor until extremely high altitudes are reached, and furthermore, the intensity of the radiation there must be very low. It is probable that this region from the soft x-rays to Lyman- α will have to be investigated by satellites; it is not very suitable for rocket work. Tousey and his co-workers have photographed the continuous spectrum of the sun and the accompanying Fraunhofer absorption lines down to about 1550 Å. Beyond this point the Fraunhofer continuum must fall off very rapidly, and the spectrum become essentially a bright line spectrum of the emission lines of carbon, hydrogen, oxygen, aluminum, silicon, sulfur, and iron

in the various stages of ionization. The strongest lines are provided by helium and particularly hydrogen. Lyman- α probably contains more energy than all the rest of the emission lines in the ultraviolet spectral region put together. These emission lines originate in the solar chromosphere and more particularly in the interface between the chromosphere and the corona. One of the most perplexing problems in solar physics at the present time is the structure of the upper chromosphere and the interface between the chromosphere and the corona. Various chromospheric models have been proposed by different investigators, and these contradict one another concerning the density and temperature variations. Most workers have attempted to explain or interpret either the radio or the optical data, but rarely both, with the result that no really satisfactory model of the chromosphere has yet been obtained. Knowledge of the detailed solar spectrum in the region from 1500 Å down to the x-rays would be of inestimable value in constructing a model for the solar chromosphere.

We must distinguish here between the phenomena connected with the quiet sun and those pertaining to the disturbed sun. A continuous surveillance or scanning of the solar spectrum would be extremely desirable in order to isolate those effects that are of a transient character. On the other hand, in order to construct suitable models for the outer envelope of the quiet sun we would want fairly high resolution scanning of the entire spectrum. Thus, solar spectrum and ultraviolet x-ray studies are of different types, one type requiring high resolution and perhaps long integration times for evaluating the structure of the quiet sun and the other type involving continuous monitoring of activity-sensitive radiations such as the hard x-rays and perhaps Lyman- α .

For certain lines such as Lyman- α it would be desirable to obtain not only the total intensity, but also the profiles. These profile measurements might help in distinguishing between different models for the solar atmosphere, particularly if they were obtained in the resonance lines of several abundant elements. Since a high resolution would be required, it is probable that these experiments could not be carried out in the early satellite work. Spectroheliograms in Lyman- α and in the resonance lines of helium are urgently needed. Probably one would want a continuous record of such spectroheliograms in order to maintain a constant surveillance of flare activity.

One experiment that could be carried out with

very simple equipment would be a measurement of the continuous background provided by the zodiacal light and the outer corona. Trustworthy measurements of zodiacal light are extremely difficult to make from the earth's surface because of the sky background, but with a satellite it should be possible to make accurate measurements of the outer corona and its variation with time.

Monitoring satellites pose different problems than do single experiment investigations in that one wants to measure one or two parameters accurately over a long period of time. Therefore it is necessary to concentrate on simple apparatus, long-life power supplies, and to make provision for the continuous telemetering of information to stations distributed over the surface of the earth. The sun offers one enormous technical advantage; in the usual optical regions it is so much brighter than any other object in the sky that tracking should be very simple. For studies of stars, planets, and nebulae the tracking poses a rather difficult problem which perhaps cannot be adequately solved until satellites of a thousand or more pounds of payload are in order. Hence the solar spectroscopic observations might be expected to come before those of stars and nebulae. It is probable that many of the techniques and procedures developed for the solar work can be carried over to the stellar and nebular investigations. The present writer has the feeling that only the brightest objects can be studied in a satisfactory way with robot satellites. For the investigation of particular faint stars and nebulae it is going to be necessary to put a man in space, as it is dubious that any fool-proof tracking mechanism can be devised that will be adequate for picking up faint elusive objects under the difficult observing conditions that are bound to prevail in interplanetary space. By the time we have to put an observer into space we should have enough information about conditions there to make it as safe as present aircraft travel.

Measurements of the ultraviolet energy from stars, nebulae, and the sky background are essential from a number of points of view. The resonance lines of the permanent gases all fall in in this spectral region. The only information we have on ultraviolet radiation from celestial sources other than the sun is that obtained from rockets fired at night by Friedman's group at the Naval Research Laboratory. The experiment is complicated by the fact that no guiding system is possible, and as the rocket rolls, the detectors

sweep out a broad band across the sky. One must find the region of the sweep by identifying known stars or objects likely to emit radiation characteristic for the spectral frequencies involved. In spite of these difficulties, information of very great significance has been obtained.

Theories of stellar atmospheres predict the energy distribution beyond the limit of the transmission of the earth's atmosphere. For the higher temperature stars a considerable distortion of the energy curves from that of a blackbody is anticipated. Unfortunately, none of these predicted energy distributions can be tested directly, and we have been forced to resort to indirect, rather unsatisfactory methods of approach. Using a broad band-pass filter in the near ultraviolet, Boggess and Dunkelman observed a number of stars in the near ultraviolet and were able to compare their colors over a long base-line in wave length. The results obtained are difficult to interpret and understand in terms of existing theories of model stellar atmospheres, and further work will have to be carried out on this problem.

For the early satellite experiments Arthur Code has proposed radiation measurements with a photometer that scans the sky with an aperture of the order of 5° and measure the integrated sky brightness at several wave lengths, the most significant being in the ultraviolet beyond the 3000 Å atmospheric limit. These measurements would provide a preliminary reconnaissance of the problem since the observed light would be due to integrated starlight, to individual bright stars, to the diffused background radiation from the galaxy, to diffuse nebulae, and also to the zodiacal light in certain regions of the sky. Code believes that the relative contributions of the various factors could be disentangled and would provide the basis for experiments planned for satellites carrying a payload of more than 100 pounds. He emphasizes that it is important to obtain absolute energy measurements and not just relative intensities from one part of the sky to another.

Complications would of course be provided in the measurement at Lyman- α . The observations by Friedman's group indicate that there is a considerable amount of back-scattering of Lyman- α radiation due to hydrogen atoms in the neighborhood of the earth. It is indeed possible that the intensity of this radiation may be so high as to make measurements of galactic sources extremely difficult. On the other hand, the scattered light may have a narrow enough frequency range, so eventually it may be possible to use some

kind of a frequency sweep to detect the radiation from extragalactic sources. This radiation will be displaced in wave length from the local scattered Lyman- α radiation by a Doppler effect.

Recent calculations show that the cool interstellar hydrogen will absorb all the Lyman emission lines produced by gaseous nebulae (such as Orion) in our own galactic system. Furthermore, even for stars in the neighborhood of the sun, the profiles of their dark Lyman lines are likely to be strongly distorted. The strong absorption in the hydrogen and helium continua will extinguish all radiation from distant stars and gaseous nebulae from $\lambda 912$ down to $\lambda 40\text{--}20$ Å in the soft x-ray region. We should be able to observe x-rays from objects such as the Crab Nebula, however.

The observations by Friedman's group with a counter whose sensitivity was centered at 1300 Å have revealed some of the most exciting problems that may be encountered in satellite astrophysics. In the first place, some of the hottest bright stars appeared to be much too faint in this spectral region if we accept the results of the model atmosphere calculations. The star, Spica, for which the line spectrum suggests an excitation temperature of $28,000^\circ$ should be about thirty times brighter than it is observed to be. Most perplexing, however, are the ultraviolet emission nebulae observed in Virgo and in Orion by Kupperian, Boggess, and Milligan. The Orion emission appeared to fill all the area out to the Barnard loop, while the Virgo nebulosity, which is centered on Spica, is associated with no visible emission at all! Speculation on the origin of this radiation must be held in abeyance until its spectrum has been observed.

Accordingly, we have on the one hand the problem of measuring the spectra of the stars and nebulae in the ultraviolet region and on the other the question of a comprehensive sky survey, preferably carried out with a fairly narrow band-pass filter. Something like Code's low angular resolutions survey would appear to be in order for the first step, but this must be followed by a more detailed investigation with a much higher angular resolution, possibly something of the order of a minute of arc, although even a degree resolution would yield useful results. Observations with a band-pass of about 100 Å width would be particularly useful at $2700, 2100, 1600, 1300, 1216, 1000$ Å, and in the x-ray region. Further observations with collimated x-ray counters would be most interesting, but here again the experimental techniques might be very difficult. Before spectral scans of bright stars and nebulae can be undertaken, however, accurate tracking

to within 10 minutes of arc will be necessary for most objects. We would suspect that interplanetary and interstellar hydrogen would absorb most of the radiation below 912 Å so that it is possible that the initial scans should concentrate on the region from 900 Å to 3000 Å. An effort should be made to obtain scans with as high a spectral resolution as possible for a group of stars covering a wide range in surface temperature.

Radio astronomy observations would be very useful for giving information on the transmission properties of the earth's atmosphere and the structure of the upper layers of the ionosphere, for example, distribution of electron densities outward from the F layer. Among the radio astronomy satellite experiments that could be made with simple long wire antennas and more or less conventional radio receivers would be the measurement of the long wave-length end of the dynamic spectra of solar radio bursts and the dynamic spectra of the radio bursts from Jupiter. The Jovian bursts are most numerous around 18 Mc, and observations at longer wave lengths are difficult because of the disturbance or blocking by the earth's ionosphere. Measurements of the range and frequency occurrence of bursts below 18 Mc would yield valuable data for testing hypotheses of the origin of this radio noise and the influence of the Jovian ionosphere. Finally, it is desirable to obtain measurements of the low frequency RF spectrum of the cosmic background at both high and low latitudes in order to disentangle the contributions of galactic and extragalactic sources and of thermal and non-thermal emission. Measurements at low frequencies could help determine the process that produces the cosmic background emission, a problem which is so important from the point of view of cosmology, galactic structure, the origin of radio sources, and cosmic rays.

It is apparent that space research is going to require an intensive effort on the part of astronomers and that many of us will have to become familiar with new and difficult experimental techniques. The rewards obtained from successful observations will, however, be well worth the effort. We have learned just enough to know that in many fields of astrophysics we cannot make much further progress until information has been obtained about what is going on in the ultraviolet of our celestial sources.

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National Academy of Sciences,
National Research Council*

ABSTRACTS OF PAPERS PRESENTED

Aller, L. H. Abundance of carbon in gaseous nebulae.

Whereas nitrogen, oxygen, neon and heavier elements are represented in gaseous nebulae primarily by their forbidden lines, carbon shows only recombination lines of which the most frequently observed is $\lambda 4267$ CII. Carbon/hydrogen ratios are estimated by an approximate theory somewhat similar to that employed by Mathis for his study of the helium/hydrogen ratio.

For the highest levels ($n \geq 7$) it is assumed that the level populations are hydrogen-like. The populations of the lower levels are then calculated by a mechanistic argument. Computations are carried out for the strongest recombination lines of CII, CIII, and CIV for $T_e = 16,000^\circ\text{K}$. Applications to NGC 7027 suggest a ratio of carbon to hydrogen of about 1.5×10^{-3} as compared with a ratio of 2×10^{-3} for oxygen. The mean C/O ratio for several nebulae including NGC 7662, 2440, and 2165 is about 0.7. Carbon and oxygen thus appear to be comparable in abundance but an accurate determination of the C/O ratio will require a more extended theoretical treatment, more accurate observations of the intensities of weak recombination lines, and a reliable determination of the distribution of atoms among different stages of ionization.

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Ann Arbor, Mich.*

Aller, Lawrence H. and Liller, William. The composition of the Orion Nebula.

Photoelectric spectrophotometric measurements of line intensities in the Orion Nebula are combined with Wyse's photographic measurements for the weaker lines to obtain the concentrations of various ions of the permanent gases. As noted by Osterbrock and others, there is evidence for large density fluctuations in this object. We have adopted a mean electron density $N_e = 4 \times 10^3$ from the forbidden lines and $T_e = 9000^\circ\text{K}$ from the photoelectrically measured $\lambda 4363/(N_1 + N_2)$ ratio. Approximate cross-sections have had to be used for sulfur, chlorine, and argon. A fairly well-defined empirical ionization curve was obtained. The following table compares the nebular abundances with those of early type stars as determined in the Michigan

program:

	log N			log N	
	Star	Nebula		Star	Nebula
Nitrogen	9.2	9.1	Sulphur	9.0	9.1
Oxygen	10.0	10.0	Chlorine	8.7	7.3
Neon	10.1	10.2	Argon	8.4	8.6

*University of Michigan Observatory,
Ann Arbor, Mich.*

Billings, D. E. Line width structure of coronal regions.

A careful and detailed study of the widths of coronal lines in various parts of coronal regions is in progress. It is hoped that this study will reveal the pattern of temperature or motion in the corona that determines the widths of the lines. One interesting result of the study to date is evidence that the widths of coronal lines begin to decline slowly with height at distances of approximately 75,000 km above the photosphere.

From the regions studied we can rule out rather definitely certain hypotheses concerning the cause of the great widths of coronal lines—specifically that the widths in excess of 6 to 7×10^5 degrees are due to outward streaming of coronal gas, either from active centers or radially from the sun, or from random motion of macroscopic aggregates of the gas. Some evidence is to be found that the contribution of the higher angular momentum states to the ionization cross-section of the coronal ions is comparable to the S-wave cross-section computed by Schwartz (see page 54).

*High Altitude Observatory
of the University of Colorado,
Boulder, Colo.*

Carpenter, E. F. and Jepperson, Richard. Color photography of faint objects with a special fast film.

For some time Carpenter at the Steward Observatory and Duncan at the Mt. Wilson and Steward Observatories have been experimenting with color film as a simple, single-exposure, qualitative color-discriminant. Carpenter and Jepperson have recently obtained and tested some samples of an experimental Super Anscochrome film of encouraging speed and color characteristics. The emulsion is rated at ASA 160 without forced development. Since it is exceptionally red-

sensitive, requiring a green-transmission filter for ordinary daylight use, the emulsion is not expected to become commercially available.

With equal exposures the emulsion is found to be 0.6 mag. faster than Super Anscochrome roll film, in keeping with the ASA ratings. At the 36-inch Steward reflector an exposure of five minutes shows 13.8 mag. faintly, but well enough to distinguish between red and white stars. Reciprocity failure is considerable, a time-of-exposure factor of 3.6 being required for an extension of one magnitude.

Color latitude is remarkable, red stars showing no appreciable dilution of color over an exposure range of 30 times, and only moderate dilution in a range of 60 times. Blue stars whiten much more rapidly with exposure time. The color latitude is much less with images of extended surfaces, since with these there is no possibility for the excess light to spread in the emulsion.

We have as yet made no comparison of the registration of color as a function of stellar color index, but the gradient of the registration seems to be very steep, so that only the extremes of color can well be recognized, for example the distinction between red and white stars.

The performance of the emulsion has been tested by photography of η Persei, NGC 1976 (M42), 1952 (M1), and the following planetaries: NGC 650 (M76), 6720 (M57), 6853 (M27), 7662. The photographs of M1 show most of the bright red filaments which appear in $H\alpha$ photographs. The dominant red, green, and blue areas of the planetary nebulae are well differentiated. Some of the edges of M27 are red, while M57 has a bright red corona.

M42 is particularly spectacular. The entire interior of the nebula is red, short exposures revealing an especially bright red edge to the central illumination southeast of the quadrilateral. On longer exposures the bright arms of the nebula which extend to the northwest and to the southeast are distinctly blue, and when the photograph is viewed with the north side upward these arms resemble a dark blue mantle draped over the red interior. There is surprisingly little spectral difference between the red and the blue areas of the nebula. With the sharp bright boundary between these areas placed across the slit, spectrograms of type F sensitivity appear identical except that the $[N\text{II}]$ lines $\lambda\lambda 6548$ and 6584 , as well as the $[S\text{II}]$ line $\lambda 6726$ are missing in the blue area of the nebula. But the color film is not sensitive as far out as $\lambda 6726$. Since $H\alpha$ appears at normal strength in the blue area of the nebula,

the tested emulsion is a very sensitive color discriminant.

*Steward Observatory,
University of Arizona
and Color Classics, Inc.,
Tucson, Ariz.*

Davis, R. J., McCrosky, R. E., Whipple, F. L. and Whitney, C. A. A plan for operating an astronomical telescope in an earth satellite.

The Smithsonian Astrophysical Observatory is developing plans for an astronomical telescope in a satellite orbit for the study of the far ultraviolet radiation from objects other than the sun. A preliminary feasibility study indicates that the device will consist of an 8-inch $f/3$ off-axis mirror, with a specialized television image-tube placed at the focus. The total configuration of optical and electronic components will be almost spherical. The orbit preferably will have an inclination of 35° to 45° , mean height of at least 500 miles, approximately circular.

Optimum reliability is achieved through centering the more complex electronic components at ground installations. The entire celestial sphere can be covered through active image transmission during long-path crossings of the United States, utilizing two control stations for satellite telescopes: a master and a slave separated by a distance of 2000 miles.

The initial experiment will map the intensity of radiation from the entire sky in four colors between 1000 $\text{\AA}$ and 3000 $\text{\AA}$ with a sensitivity and resolution that will allow us to record a minimum average of 10 stars per square degree, with an angular resolution better than 1 minute of arc. The sensitivity will be adjustable over fairly wide limits.

*Harvard College Observatory
and Smithsonian Astrophysical Observatory
Cambridge, Mass.*

Gaposchkin, Sergei. The visual Milky Way.

The major part of the visual panorama of the whole Milky Way (see p. 58) done with a pen in India ink was drawn during my stay in Australia in 1956-57. The main features are as follows:

Around Ophiuchus, Sagittarius, and Scorpius there is a definite extended halo or bulge which is much more clearly outlined visually than on any set of photographic pictures. From the right side (Centaurus) the bulge is sharply outlined by a "Ditch" which begins at α Centauri and ends at α Scorpii; on the left side it is less sharply outlined by the "Sweep" in Ophiuchus. The "Coal Sack" has to its right a "Coal Scuttle" in Carina;

and further to the right lies an S-shaped formation in Vela-Puppis. Between Puppis and Ophiuchus lies the brightest and most dramatic part of the visual Milky Way. This part is also more whitish in color than the rest. Although the Milky Way in Sagittarius is on the whole the most luminous, the brightest spot of the Milky Way lies visually around η Carinae. The faintest part of the Milky Way lies in the "Backyard" region of Auriga. The dark matter appears to form a continuous belt whose length and breadth is broken in a few places. Beginning in the faintest region, Perseus, the dark strip is easily traced on the luminous blotches of Cassiopeia, Cygnus, Aquila, Ophiuchus, Sagittarius, Centaurus, Carina, Vela, Puppis, Canis Majoris, Orion, and Auriga. In other words, the dark girdle pierces the Milky Way in its midriff and thus divides the Milky Way in two almost equal parts. With the aid of this visual sketch of the Milky Way, one can draw a profile of the Milky Way as seen at a great distance from the sun.

The luminous areas of the Milky Way were quantitatively expressed in terms of the Large Magellanic Cloud, which I estimated to be -1.0 mag. visually. As the Milky Way was rolling up and as I was moving from place to place (Australia, Indonesia, India, Europe, and Massachusetts) the different luminous parts of the Milky Way were intercompared in estimation of brightness. Thus it was possible to express the brightness of the whole circuitous span of the Milky Way on a uniform scale. For example, the brightest region in the north (Carina) is -3.5 mag., that in the south (Sagittarius) is -3.2 mag., the brightest cloud in Cygnus is -1.0 mag., and the whole Milky Way is -5.5 mag.

*Harvard College Observatory,
Cambridge, Mass.*

Halliday, Ian. Auroral green line and collision effects in meteor wakes.

New observational material on meteor wakes has been obtained at Meanook and Newbrook, Alberta, Canada, during 1958. Five spectrograms showing the auroral green line have been secured. The line is observed between heights of 115 and 79 km. The cameras were occulted 12 times per second but there is no perceptible decay of the green line across the occulted portions of the trails. An upper limit of not more than 5 de-exciting collisions per second for the metastable oxygen atom is derived. The light curves indicate that in those cases where the line disappears

at relatively great heights the cause is a lack of some reagent, presumably atmospheric oxygen in atomic form, rather than an increased importance of de-exciting collisions. The persistence of the green line below 90 km is surprising, since, in addition to more than 10^4 collisions per second with atmospheric particles, collisions with ablated meteor atoms become frequent and might be expected to quench the forbidden line. The height to which the green line remains visible appears to be correlated with local geomagnetic activity. The line is observed down to lower heights at times of increased activity.

Two high-dispersion spectrograms of a bright Perseid were secured, one of which shows a strong wake spectrum. The magnesium plus iron feature near $\lambda 5176$ is resolved in the wake and confirms that iron is the main contributor to this wake feature. A combination of the two spectrograms shows that iron atoms released at the terminal flare coasted for 180 meters before the energy of re-exciting collisions dropped to an optimum for the lowest iron multiplets. The deceleration is reasonable for coasting atoms but not for solid particles.

*Dominion Observatory,
Ottawa, Canada*

Hawkins, G. S., Southworth, R. B. and Stienon, F. Recovery of the Andromedids.

The spectacular displays of the Andromedid meteors in 1872 and 1885 have never been repeated and they have often been listed as a "lost stream." Precise photographic measurement with the Harvard Super-Schmidt cameras over the period 1952-56 have disclosed 24 meteors that follow the orbit of Biela's comet and represent the remnants of the swarm. The individual orbits show evidence of perturbations caused by the earth and Jupiter. It is deduced that the orbit of the Andromedid swarm now passes 0.05 a.u. below the earth's orbit. The Andromedid meteors described here have been perturbed in the plane of the comet orbit, similar to the dispersion observed in the sunward tail of the comet Arend-Roland.

*Harvard College Observatory,
Cambridge, Mass.*

Henize, Karl G. A new planetary nebula NGC 6164-65 (Cederblad 135a, b).

Objective-prism photographs of NGC 6164-65 taken in the light of $H\alpha$ and $[NII]$ in the course of the Michigan-Mount Wilson $H\alpha$ Survey show a markedly symmetrical distribution of gas about

the central star HD 148937 (Harvard spectral class B0). The shape of the nebula is roughly that of a figure "8" with small knots in the nebulosity showing central symmetry. These details are confirmed on direct photographs obtained with the 48-inch Schmidt.

The apparent brightness ($6.89 m_{pg}$) of the central star is greater than that of any other planetary nucleus. Assuming the nucleus to be a main sequence B0 star, Cederblad derived a distance of 670 parsecs. If, as seems more likely, it is a subluminescent B or O star comparable to other planetary nuclei, its distance is reduced to about 150 parsecs.

The $370''$ angular diameter of the nebula is the fourth largest on record. At a distance of 670 parsecs this yields a linear diameter of 1.2 parsecs; while at 150 parsecs the derived linear diameter is 0.27 parsec.

This object is clearly a planetary nebula from a morphological viewpoint, but spectroscopic observations of the nebula and central star are required to determine whether or not it fits this description from an evolutionary point of view. Whatever the result, the object is of unusual interest and deserves further investigation.

*Smithsonian Astrophysical Observatory,
Cambridge, Mass.*

Hynek, J. A., Henize, Karl G. and Whipple, Fred L. Report on the precision optical tracking program for artificial earth-satellites.

The photographic tracking program for IGY artificial earth-satellites operated by the Smithsonian Astrophysical Observatory employs a network of 12 observing stations around the world which uses the 20-inch, $f/1$ Baker-Nunn Schmidt satellite tracking camera especially designed for satellite tracking purposes.

Since 5 July 1958, all 12 stations have been in operation and the optical performance of the Baker-Nunn cameras has fulfilled the original design specification which called for $20\text{--}25\mu$ diameter stellar images. Mechanical performance, which called for rapid cyclic operation at essentially satellite and stellar angular rates, and a photographic time presentation have likewise proved satisfactory.

Photography of all satellites aloft except the Vanguard 1958 β has been routine. 1958 α has, since 5 July 1958, been photographed at the rate of 2.05 transits per day, with multiple photographs obtained per transit. The $6''$ Vanguard

satellite has been successfully photographed at a distance of more than 900 miles.

The Army satellite, Explorer IV (1958 ϵ) has, after 27 July, been photographed at 0.81 transit per day. Rapid reduction of the Explorer photographs were made to provide minute-by-minute space positions for evaluation of the radiation counts made by the Geiger and scintillation counters carried by Explorer IV.

All satellite photographs are reduced roughly at the respective stations. Later, machine reduction is made at the tracking headquarters in Cambridge. Standard reduction techniques with both the Van Biesbroeck goniometer and the Mann two-screw measuring engine are used. These data will be published and will include: 1. α and δ and estimated p.e.; 2. position angle of satellite motion and estimated p.e.; 3. time (UT_2) and estimated p.e.

Using 117 measures of variable quality, the estimated probable errors are $5''.4$ in α and $4''.0$ in δ ; but using 13 images of best quality, the mean estimated probable errors of a single satellite position are $1''.1$ in α and $0''.5$ in δ .

The larger error in right ascension reflects the greater error in setting on satellite positions in the direction of satellite motion, which to date has been predominantly west to east.

*Smithsonian Astrophysical
and Harvard College Observatories,
Cambridge, Mass.*

Koch, Robert H. The eclipsing binary, XY Leonis.

Photoelectric light curves were obtained in both yellow and blue light over a four month period in 1956. Additional observations place the variable on the (U, B, V) system and indicate it to be composed of similar late dwarfs.

The period of light variation is not constant and does not vary in a simple manner. To describe the outside-eclipse variations a term in $\cos 3\theta$ is necessary in both colors. Various methods of rectifying the observations are attempted, and it is shown that the final results do not depend greatly on the particular method chosen. The rectified eclipses are photometrically shallow but geometrically deep, and determinate solutions for the elements of the system have been derived. The discrepancies between the solutions are discussed, and a tentative model for the system is proposed.

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Philadelphia, Pa.*

Osterbrock, Donald and Stockhausen, Ralph.
Photoelectric photometry of diffuse nebulae.

A five-inch $f/5$ refracting telescope has been constructed at the Pine Bluff station of the Washburn Observatory for photoelectric photometry of emission nebulae. With this telescope it is possible to measure a field as large as $20'$ in diameter at a single exposure, and to compare objects in different parts of the sky rapidly. Interference filters may be used in the photometer to isolate nebular emission lines, and we have begun a program of measuring surface brightnesses with a 1P21 photocell and a filter that transmits $H\beta$ and the $[OIII]$ green lines. The calibration to energy units is provided by measurements of bright planetary nebulae previously observed by Liller and Aller, and also by measurements of stars with known spectral energy distributions. The idea of this program is that from the measured total emission of the nebula in a hydrogen line, one can find by Zanstra's method the total emission of the exciting star in the continuum beyond the Lyman limit. This measurement, together with the known visual magnitude of the star, thus provides a wide-baseline color index, and hence is a powerful check that may be applied to test the correctness of model atmospheres of early-type stars.

It is essential that the nebula be excited by the minimum number of stars, and completely absorb their ultraviolet radiation, so we have selected as an example NGC 281, excited by the O6 star HD 5005 br. The nebula is surrounded on most of its circumference by dark neutral matter, and hence is known to be a nearly complete Strömgren sphere. Our measurements of NGC 281 show that the ratio of extreme ultraviolet ($\lambda < 912\text{\AA}$) to visual radiation in HD 5005 br is somewhat below the ratios predicted by published model atmospheres for O stars, but observations of other nebulae are necessary to be sure that this is not simply an effect of incomplete absorption.

Washburn Observatory,
Madison, Wis.

Page, Thornton. Masses of the double galaxies.

My initial study, published in 1952 (*Ap. J.* **116**, 63) has been extended and refined to include 65 pairs of galaxies for which radial velocities are known, including 82 velocities from the Humason-Mayall list and 60 measured by the author. The mean mass of a galaxy derived from these data is inversely proportional to the Hubble constant in the velocity-distance law; if this constant is

$10^{-4} \text{ km sec}^{-1} \text{ psc}^{-1}$, the mean mass is 2.5×10^{11} suns, and the mean ratio of mass to luminosity is 18, in solar units.

The data can be divided into two groups: for 45 pairs involving elliptical or So galaxies, the mean mass is 4×10^{11} suns and mean M/L is 41; for 20 pairs involving only spiral and irregular galaxies, $\bar{M}$ is 0.3×10^{11} and mean M/L is 1.3, in solar units. Moreover, individual cases yield lower limits to M and M/L in the neighborhood of 5×10^{11} suns and 18, respectively (for NGC 5898–5903).

Van Vleck Observatory,
Wesleyan University,
Middletown, Conn.

Rabe, Eugene. The orbital motion of the minor planet (1362) Griqua and the mass of Jupiter.

The minor planet (1362) Griqua is of special interest not only because of its mean daily motion n which is continuously increasing from $596''$ in 1933 to $607''$ in 1977, going through the rigorous 2 : 1 commensurability with respect to Jupiter's mean motion n' during the year 1943, but also because of the large eccentricity e of its orbit, which makes it possible to observe the enormously large perturbations by Jupiter in perihelion oppositions at such close geocentric distances as 1.3 a.u. When the orbital elements of the planet were derived from accurate positions in 6 oppositions during 1935–1956 (Rabe 1956), the final values of the accurate special perturbations computed on NORC as well as of the elements were obtained only by a process of successive approximations, because of the size of the perturbations by Jupiter and their dependence on the basic elements.

In Table I the two significant elements n and e

TABLE I. n AND e WITH INTERVALS OF 800 DAYS

JD	n	e	JD	n	e
27400.5	596".10	0.33975	36200.5	602".98	0.35256
28200	596.19	.34051	37000	602.84	.35314
29000	596.18	.34108	37800	603.17	.35383
29800	596.87	.34189	38600	603.92	.35454
30600	596.71	.34237	39400	603.65	.35544
31400	598.93	.34525	40200	606.00	.35766
32200	599.79	.34667	41000	606.37	.35856
33000	599.43	.34712	41800	606.28	.35907
33800	600.00	.34811	42600	606.93	.35994
34600	600.80	.34838	43400.5	607.22	0.36020
35400.5	601.41	0.35049			

have been listed with intervals of 800 days, beginning at JD 2427400.5 = 1933 Nov. 24.0 UT, and ending at JD 2443400.5 = 1977 Sep. 14.0 UT. These osculating values of n and e include the perturbations by all the major planets from Venus to Neptune, but Jupiter is almost exclu-

sively responsible for the remarkable orbital changes exhibited in Table I. From earlier long range computations for a fictitious case of such a critical Hecuba planet (Wilkins 1930) we know already that the longitude perturbations by Jupiter are of zero order and are not limited to any maximum amplitude. The purpose of this note is to point out that in the case of Griqua such rapidly increasing perturbations can be observed under most favorable conditions, and that apparently Griqua is a most suitable asteroid for the determination of Jupiter's mass.

The size of the total perturbational displacements $\Delta\alpha \cos \delta$ and $\Delta\delta$, observable in the next three perihelion oppositions 1959, 1965 and 1971, has been computed for two dates 20 days apart in each of these most favorable oppositions. These values are listed in Table II, together with

TABLE II. PERTURBATIONAL DISPLACEMENT OF GRIQUA IN COMING PERIHELION OPPOSITIONS

Date UT	ρ	r	$\Delta\alpha \cos \delta$	$\Delta\delta$	Δs
1959 Sep. 29.0	1.270	2.118	+24°.89	+ 6°.12	+25°.63
Oct. 19.0	1.267	2.109	+24.34	+ 4.60	+24.77
1965 Oct. 27.0	1.293	2.123	+40.73	+12.83	+42.70
Nov. 16.0	1.300	2.148	+38.26	+10.51	+39.68
1971 Nov. 25.0	1.384	2.259	+57.33	+20.70	+60.96
Dec. 15.0	1.406	2.313	+51.97	+18.18	+55.06

the total displacement Δs , the geocentric distance ρ , and the heliocentric distance r . The zero epoch of these perturbations is 1935 July 31.903, corresponding to the first observation known for this planet. In 1971, or 35 years later, the observable effect of Jupiter's mass amounts to 61°.

Observers are urged to observe Griqua as extensively as possible, not only in these perihelion oppositions but in regular oppositions as well. Extended ephemerides will be published in the MPC. The author intends to utilize all suitable observations later on for a determination of the mass of Jupiter.

REFERENCES

- Rabe, E. 1956, *Minor Planet Circ.* 1459.
Wilkins, A. 1930, *A. N.* 240, 201.

University of Cincinnati,
Cincinnati, Ohio

Schwartz, Sanford B. Ionization cross-section of FeXIV by electron collision and the electron coronal temperature.

A new calculation for the ionization cross-section of the $3p$ electron of FeXIV by electron collision is given, where a hydrogen-like model is used for the atom. The continuum functions are made to approach Coulomb functions at large

distances from the atom. Only the S-partial waves of the incoming particle are here included, and the resulting cross-section is more than a factor of 10 smaller than the semi-classical values previously used (e.g., Elwert, G., *Z. Naturforschung* 7a, 342, 1952) by others to deduce coronal temperature from optical spectra. The use of this new calculation for estimating coronal temperatures indicates that the electron temperature is around 2×10^6 °K.

This work was supported in part by Office of Naval Research contract Nonr 393(04).

High Altitude Observatory,
Boulder, Colo.,
now at Physics Dept., U. of Nevada, Reno, Nev.

Sterne, Theodore E. The effect of the rotation of a planetary atmosphere upon the orbit of a close satellite.

Drag in the stationary atmosphere of a planet causes the mean distance, a , and eccentricity, e , of a satellite to decrease secularly, but causes no secular changes in the argument ω of pericenter, the inclination i , or the longitude Ω of the node. The decreasing period, caused by the decreasing a , has been used to infer the density of the earth's atmosphere at great altitudes from the decreasing periods of artificial earth satellites. Rotational flattening of the planet leaves a , e , and i secularly unchanged but causes secular changes in Ω and ω , varying inversely as $a^{7/2}$. Combined effects of drag and flattening thus cause secular accelerations of the node and pericenter.

Wildhack, of the National Bureau of Standards, has considered the effect of atmospheric rotation upon i , and the author has more recently derived formulae for all the secular effects of general atmospheric rotation. Atmospheric rotation in the same sense as a satellite, by decreasing drag, decreases the rate of diminution of a . Neglect of this effect has led to a slight underestimation of the earth's atmospheric density. The rate of decrease of e is also diminished. The inclination is caused to decrease, at a rate dependent upon $(1 + \cos 2\omega) \sin i$ whose secular value is $\sin i$. For the artificial earth satellite 1957 $\alpha 2$, i should have decreased by about a second of arc a day. The node is caused to regress at a rate proportional to $\sin 2\omega$ and ω to increase at a rate $\cos i$ times as great. Since the planet's rotational flattening changes ω secularly, atmospheric rotation does not change Ω and ω secularly.

Smithsonian Astrophysical Observatory
and Harvard College Observatory,
Cambridge, Mass.

Underhill, Anne B. Some spectrophotometric observations of the Wolf-Rayet stars HD 192103 and HD 192163.

The following claims regarding Wolf-Rayet stars may be found in the literature: (1) that all Wolf-Rayet stars are binaries, (2) that the color temperatures of Wolf-Rayet stars determined spectrophotometrically over the range $\lambda 3900$ to $\lambda 5000$ are of the order of $12,000^\circ$, and (3) that no N lines are to be found in WC spectra and no O lines in WN spectra. These conclusions obscure the relationship of the Wolf-Rayet stars to the rest of the stellar population.

Grating spectrograms at $16\text{\AA}/\text{mm}$ have been obtained of HD 192103 and HD 192163 covering the range $\lambda 3100$ to $\lambda 4500$. This material was supplemented by prismatic spectrograms of moderate dispersion ($30\text{\AA}/\text{mm}$ at $H\gamma$) covering the range $\lambda 4000$ to $\lambda 6800$. The following comments may be made:

(1) The radial velocity of each star was obtained on 4 nights in 1957–58, and it does not vary by an amount in excess of 30 km/sec. The scatter among the results can be entirely accounted for by the random errors of measurement. No absorption features attributable to an O or B type companion are visible in the spectrum of HD 192103 or of HD 192163. Thus these stars do not have companions of absolute magnitude brighter than -1 . A fainter companion could not readily be detected.

(2) There are many weak emission features in both spectra in addition to the well-known strong lines. Thus both spectra rarely dip to the continuum. The continuous spectrum that was finally derived after studying tracings from $\lambda 3100$ to $\lambda 6800$ is very like that of an O star. It does not look like that of a star which has a color temperature of $12,000^\circ$ and there is no Balmer jump in absorption or emission. Slitless spectra will be required to obtain meaningful quantitative measurements of the continuous spectrum.

(3) A list of wave lengths has been compiled from measurements made on microphotometer tracings. This list is more comprehensive than previous lists and gives evidence that $N\text{III}$, $N\text{IV}$ and $N\text{V}$ occur in WC spectra, the clearest nitrogen line being $N\text{III } \lambda 6455$. The spectra of $O\text{III}$, $O\text{IV}$ and $O\text{V}$ are present in the WN spectrum, particularly in the ultraviolet. There is an unmistakable $O\text{V}$ emission occurring as a weak feature between $\text{HeII } \lambda 5411$ and about $\lambda 5470$.

*Dominion Astrophysical Observatory,
Royal Oak, B. C., Canada*

Weston, Edwin B. The apparent distribution of faint emission-line and variable stars in galactic nebulae.

A comparison of the relative distribution of faint emission-line and variable stars located in galactic nebulae reveals distinct differences from nebula to nebula. This paper deals with the distribution of stars in single interstellar clouds and not in the larger cloud complexes. The two extreme cases observed are (1) an apparent concentration of these stars, in the absence of any very hot, highly luminous star, about the edge of a cloud of high opacity, and (2) an apparent concentration of these stars toward the region of a hot, highly luminous star embedded in a bright nebula. Intermediate situations occur dependent upon the temperature and luminosity of the brightest star involved in the cloud and how long it has been shining with its present characteristics. In case (1) small reflection nebulae (which are small regions in the cloud) may be relatively frequent when seen against the dark cloud, but not as frequent when seen at the edge except when the rim is bright. The small reflection nebulae will be less frequent in case (2).

This effect can be explained in terms of differential dissipation and concentration of interstellar material by radiation pressure and gravitational forces. In the first case we see these faint stars only when they are on the periphery of the interstellar cloud. A star in the near side of the cloud, but seen more or less centrally against it, will frequently show a reflection nebula since its light is scattered by dust behind, to the side, and especially in front of the star, whereas a star appearing on the edge of the cloud will usually be in a region of lower density of interstellar material and in a less favorable geometrical situation for observing a reflection nebula. In the second case the radiation pressure of the very hot, highly luminous star will have blown outward the interstellar dust, which will carry with it a portion of the interstellar gas, thus decreasing the obscuration and revealing the faint stars in the deep interior of the cloud.

T Tauri variables with more extreme characteristics are found only in case (1). Orion variables are present in both cases, but especially in case (2). Neither are found outside of galactic nebulae. This is interpreted to mean that a certain density of interstellar dust is required for T Tauri variables, whereas interstellar gas is sufficient for Orion variables. Probably the Orion variables represent a transition stage in the evo-

lution of T Tauri stars into dwarf flare stars or other stars near the main sequence in the H-R diagram.

*Amherst College Observatory,
Amherst, Mass.
and Smith College Observatory,
Northampton, Mass.*

White, Marvin L. Oscillatory currents in the ionosphere.

The solar thermal and gravitational excitation of oscillations in the earth's ionosphere is responsible for the production of "worldwide" atmospheric current systems and "quiet day" magnetic variations at the earth's surface. A proper theoretical approach to this problem, attempted here, involves the extension of the resonance tidal theory initiated by Taylor and Pekeris for a neutral component atmosphere so as to include traces of an ionized component in the presence of the earth's dipole field. Also necessary to the problems is a theory for formation of the electrified atmospheric layers by solar ionizing radiation, day and night effects included. Layers so formed are said to be solar controlled. Large distortions from this condition of strict solar control are produced in the F-layers by thermal and tidal oscillatory motions. It turns out that the theory is, in essence, nonlinear due to thermal excitation of sum and difference frequencies by an I^2R source function (electrodynamic viscosity). Even for the lower un-ionized regions of the earth's atmosphere, Stokes' "dissipation function," of second degree, accounts for observable nonlinear effects. The end result in the theory is, in part, to predict spacial and temporal variation of ionospheric electron densities; in Schuster and Chapman's previous dynamo theory, height variations of the current system were ignored as the ionosphere was idealized as a thin shell.

*National Bureau of Standards,
Boulder, Colo.*

Wilson, Raymond H., Jr. A gravitational force function for the earth representing all deviations from a spherical geoid.

In the present treatment each area of deviation from a uniform spherical gravitational field is represented by a separate series of Legendre polynomials having its pole of reference centered on the area. Thus the earth's north and south polar oblateness deviations are represented sepa-

ately so that their inequality can be investigated. The series for minor deviations centered at general latitudes and longitudes has been transformed to terms of variables in the inertial coordinate system for practical computation. The vector sum of these expressions for the earth's spherical gravitational field and its deviations, together with explicitly presented geocentric expressions for the fields of the moon and sun, would thus constitute a complete force function for satellite orbit development by numerical integration.

*U. S. Naval Research Laboratory,
Washington, D. C.*

Wood, Frank Bradshaw. The eclipsing variables, TZ Corona Austrini, V Tucanae, RS Leporis, ST Carinae.

The following systems were selected for observation because the published data assigned them the following characteristics: Algol-type light curve, spectral class A, periods of from 17 to 30 hours, and deep primary eclipses with duration from 3 to 6 hours.

The short periods mean either extraordinarily large masses or small distances between the components. Similar systems which have undergone detailed analysis have shown normal masses for the brighter components; this, plus the short period, calls for a distance between components so small that the radii of the brighter components can only be about $\frac{1}{2}$ those of normal A stars; this in turn locates the A components below their normal place in the HR-diagram. The secondary components in such cases have frequently been found to fill the limiting Jacobian surface and hence are in an interesting evolutionary stage. Lack of appreciable light change between eclipses, in such close systems can be most simply explained by a large mass-ratio. If this explanation survives detailed analysis, the fainter components of these systems must have abnormally low masses.

The photoelectric light curves obtained of these four stars in general confirm the earlier photographic work, and are now being subjected to detailed analysis. The chief features of the different systems follow. Attention is called to the importance of spectrographic observation.

TZ Cr A New: JD 243 6080.035 + 0^d68674954
E. There is no strong evidence for change of period. Depths of eclipse: yellow 0.73 mag., 0.12

mag.; blue 0.73 mag., 0.10 mag. Secondary is central; light is nearly constant between eclipses; there is some reflection effect. There is some suspicion of intrinsic variation. The eclipse is probably partial; duration = $0^d14 = 3^h 22^m$.

V Tuc New: JD 243 6139.142 + 0.87091649 E. There is no evidence for change of period. Depths of eclipse: yellow 2.40 mag., 0.11 mag.; blue 2.84 mag., 0.08 mag. Secondary is central; light is nearly constant between eclipses, but third quarter is 0.05 mag. lower than first. There is suspicion of intrinsic variation. The eclipse is probably partial; duration = $0^d18 = 4^h 19^m$. There is some reflection effect.

RS Lep New: JD 243 6191.148 + 1.2885439 E. The period has apparently been constant during the interval in which the system has been observed. The curve is Algol type. There is a constant phase of about 25 minutes duration. Depths of principal eclipse: yellow 1.4 mag.; blue 1.7 mag. Duration = $0^d22 = 5^h 17^m$.

ST Car This does not show an Algol-type curve, but exhibits appreciable curvature between eclipses. Ranges are 1.14 mag. and 0.32 mag. in the yellow and 1.18 mag. and 0.28 mag. in the blue in primary and secondary respectively.

*Flower and Cook Observatory,
University of Pennsylvania,
Philadelphia, Pa.*

Wyller, Arne A. Anomalous C^{13} features in the spectrum of 19 Piscium.

In the course of a vibrational temperature study for the C_2 and CN molecules on a high dispersion plate ($5.9 \text{ \AA}/\text{mm}$) of 19 Piscium (No. C6₂) there was noted a definite absence of any pronounced structure of the $C^{12}C^{13}(0, 2)$ band at $\lambda 6168.1$. A superposition of the normal and isotopic origin-to-head structures failed to reveal any common pattern of intensity variations. In the isotopic band region, $\lambda\lambda 6168.1 - 6161.1$, the multiplets of $CaI(3)$ and $CaI(20)$ are clearly visible, as are also several of the $C^{12}C^{12}(0, 2)$ rotational line triplets. If the absorptions due to

these features are subtracted from the observed equivalent width of the isotopic region, the remaining absorption leads to a $C^{12}:C^{13}$ ratio greater than 10:1 on the thin layer hypothesis. This is significantly higher than the previously established value 3:1, based on the relative intensities of the $(1, 0)C^{12}C^{12}$ and $C^{12}C^{13}$ bands at, respectively, $\lambda 4737$ and $\lambda 4744$. The ratios of the restintensities of the isotopic to the normal line features near the heads yield abundance ratios greater than 10:1. Likewise the relative intensities of the $C^{12}C^{12}R(14)$ and $C^{12}C^{13}R(14)$ triplets yield even higher ratios than 10:1. It is found that $C^{12}C^{13}R(14)$ coincides with a "continuum window" at $\lambda 6131$.

The evidence from the red $(4, 0)$ CN band at $\lambda 6192$ definitely confirms the above findings. Within the $C^{13}N^{14}R_2(4, 0)$ region there again appears a "continuum window" at $\lambda 6247$. The derived abundance ratios are higher than 10:1. The so-called "6260 band" coincides rather well with the mean position of the R_1 and Q_1 branches of the $C^{13}N^{14}(4, 0)$ band on low dispersion plates. In the present spectrum the band occurs in reality at $\lambda\lambda 6258-6259$ and is composed of two very strong $Ti(104)$ lines, one $ScI(3)$ line and one $Vi(19)$ line, all flanked by two $C^{12}N^{14}$ rotational lines.

In the infrared $(2, 0)$ CN band-six continuum windows have been found at, respectively, $\lambda 7902.4$, $\lambda 7955.3$, $\lambda 7966.1$, $\lambda 7988.6$, $\lambda 8036.5$, $\lambda 8061.5$. One would expect very strong $C^{13}N^{14}$ absorption features in these regions but instead probably continuum emissions are observed. Unfortunately the photometry does not permit any rigorous quantitative abundance estimates. However the observed emission strengths are clearly incompatible with abundance ratios of the order of 3:1.

The conclusion is that for 19 Piscium the $C^{12}:C^{13}$ ratio has to be revised upwards to well above 10:1. Either the observed $C^{12}C^{13}(1, 0)$ feature at $\lambda 4744$ is spurious like the "6260 band" or we have a strange case of selective emission possibly due to recombination effects.

*Sproul Observatory,
Swarthmore College,
Swarthmore, Pa.*

TITLES OF ADDITIONAL PAPERS PRESENTED AT THE MEETING IN GAINESVILLE, FLA

- Abt, Helmut A. Abundance differences between high- and low-latitude supergiants.
- Alden, H. L., Osvalds, V. and Risley, A. Margurite. Proper motions and absolute magnitudes of long-period variable stars
- de Vaucouleurs, G. and Young, A. T. A statistical study of the variable opacity of the atmosphere of Mars to blue light, 1926-1956.
- Deutsch, Armin J. and Merrill, Paul W. Gross differences between the R Cygni spectra at two successive maxima.
- Field, George B. Scattering by free electrons in nuclear emission galaxies.
- Ford, W. K. Jr., Hall, J. S. and Baum, W. A. Astronomical observations with a cascaded image converter.
- Gasteyer, Charles E. The α Centauri system.
- Greene, Edward P. Mass of the Coma Cluster of galaxies.
- Johnson, H. L., Neville, R. de F. and Iriarte, B. A method of improving the photographic limiting magnitude of an astronomical telescope.
- Merrill, Paul W. Hose effect in AG Pegasi.
- Nielson, G. J., Markey, W. R. and Hynek, J. A. Stabilization of astronomical instruments for use in high-altitude balloon systems.
- Sinton, William M. Further evidence of vegetation on Mars.
- van den Bergh, Sidney. Cepheids and galactic structure.
- . The evolution of galaxies.

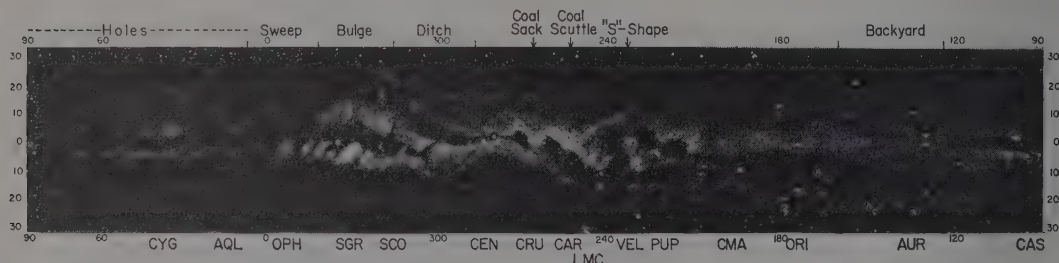


Figure 1. Visual representation of the whole Milky Way with bright stars and Large Magellanic Cloud, drawn by S. Gaposchkin, 1956-57 (see page 50).

MAGNITUDES AND COLORS IN ω CENTAURI

By EMILIA PISANI BELSERENE

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Abstract. A color-magnitude diagram and luminosity function for ω Centauri have been derived from two-color photographic photometry, calibrated by means of photoelectric magnitudes on the B, V system.

In 1956 the Royal Observatory at the Cape of Good Hope undertook photoelectric and photographic observations in the globular cluster NGC 5139, ω Centauri, to be used by the Rutherford Observatory for a photometric study of the cluster. The results of that study are reported here.

The photographic material consists of five plates of the southwest quadrant of the cluster, taken with the 74-inch reflector of the Radcliffe Observatory at Pretoria. Information about these plates is collected in Table I. The plate-filter combinations are those of the B, V system.

TABLE I. PLATE MATERIAL

No.	Emulsion	Filter	Exposure	Diaphragm
B1	103a-O	GG 13	30 ^m	none
B2	103a-O	GG 13	25	44 inch
V1	103a-D	GG 11	40	none
V2	103a-D	GG 11	40	44 inch
V3	103a-D	GG 11	5	44 inch

The photoelectric material consists of magnitudes on the same system for a sequence of stars in the same part of the cluster, observed at the Cape (Arp 1958) and also at Pretoria. The photoelectric magnitudes are in Table II, where

TABLE II. THE PHOTOELECTRIC MAGNITUDES

Star	X	Y	B	V
A	8496	992	9.86	8.59
B	8971	297	8.81	8.83
C	7803	777	10.22	9.10
D	8783	585	11.18	10.07
E	8709	982	11.26	10.10
F	8746	931	12.77	11.20
G	8470	874	13.09	11.47
H	7635	777	12.49	11.89
I	8676	515	13.69	11.97
J	8441	798	12.38	11.98
K	8420	838	13.14	12.73
L	8566	815	14.10	13.15
M	8203	958	14.45	13.67
N	8305	794	15.51	14.36
O	7783	813	15.96	14.86
P	8466	1035	16.24	15.19
Q	8419	1019	17.38	16.55
R	8414	874	17.21	16.66
S	8473	923	17.56	17.16
T	8389	1024	18.00	17.66
U	8558	1011	18.58	—
V	8441	769	19.15	19.15
W	8421	755	19.61	—

the stars are identified by their rectangular coordinates as read from the photographic photometer. When a coordinate is negative its complement is given instead. These coordinates are related to the ones used by W. C. Martin (1938) accordingly to

$$x = +0.5625 X, \quad y = -0.5625 Y,$$

where x and y are in seconds of arc measured eastward and northward, respectively, from the point which Martin adopted as the center of the cluster. The coordinates in this paper are good to within one second. Several of the sequence stars are marked in Figure 1. The others can be identified without ambiguity by their relative coordinates.

For the photographic photometry a representative sample of the stars in the cluster was chosen as follows: first, stars brighter than about

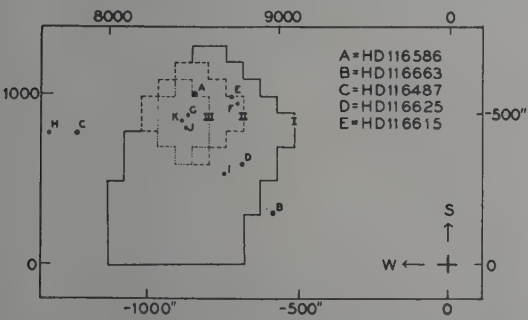


Figure 1. Diagram of the south-preceding section of ω Cen. The center of the cluster is at the cross. Coordinates are marked in seconds of arc at bottom and right, and in the unit of Tables II and III at top and left.

$B = 17$ in the region of the cluster that is marked I in Figure 1; second, stars visible on either plate B2 or V2 in a portion of that region, the part marked II in Figure 1; and, finally, all stars visible on the deep blue plate, B1, in a still smaller region, that marked III in Figure 1. All images brighter than these limits were inspected and measured if possible. With a few exceptions plates B1 and V1 were used only at magnitudes fainter than 18.0, plates B2 and V2 at magnitudes brighter than 19.0, and plate V3 above 16.5. Whenever an image was found to be too badly blended for a reliable measure, the magnitude was estimated. The measures were made with the variable-iris photometers at the Rutherford Observatory.

The magnitude scales are uncertain by about 0.1 mag. above the seventeenth magnitude, 0.2 at the nineteenth, and as much as 0.3 at the twentieth. This is due to the small number of photoelectric standards, and to their distance from the plate centers, which has caused some coma. The size of the field error has been estimated by comparison of plate B2 with plates from the Yale-Columbia Southern Station, whose 26-inch refractor is known to have a negligible field error. It appears that with the 44-inch diaphragm the field error on the 74-inch plates reaches a maximum value, in region I, of 0.12 mag. near the fourteenth magnitude and 0.07 near the sixteenth. The probable error from the internal agreement is ± 0.03 for stars brighter than the sixteenth. Information about the field error as it affects the fainter stars on the program comes from intercomparison, at the eighteenth magnitude, of the observations with full aperture and with the diaphragm. The maximum value on plates B1 and V1 is 0.09 in region III, the only sample of the cluster to be investigated on these plates. The probable error from the internal agreement is ± 0.08 at the eighteenth magnitude. The accuracy of the faintest magnitudes remains unknown. A considerable decrease in precision can be expected, due primarily to random variation in the amount of background light. Extrapolation of the magnitude scales was terminated at the twentieth magnitude.

The results of the photometry are given in Table III, where, as in Table II, the stars are identified by their coordinates. This catalogue contains only those stars which have uncrowded images susceptible to reliable measurement, but the rest of the stars on the program are included in the star counts that are discussed below.

TABLE III. MAGNITUDE CATALOGUE

X	Y	B	V	X	Y	B	V	X	Y	B	V	X	Y	B	V
8083	20	17.16	16.64	8740	374	15.58	14.56	8480	625	15.95	14.95	8503	715	19.34	19.02
8175	12	16.80	15.90	8779	324	17.09	16.67	8482	592	18.01	18.81	8507	773	18.40	18.49
8243	70	15.53	14.38	8798	318	16.23	15.57	8484	641	18.99	19.03	8573	742	18.83	19.53
8277	0	17.22	16.66	8805	332	15.71	15.41	8488	654	15.92	15.09	8575	731	18.23	18.24
8300	48	16.52	15.83	8818	295	14.85	13.52	8487	682	19.19	19.10	8585	694	18.08	18.00
8313	47	16.71	15.88	8844	345	16.68	16.14	8495	594	18.45	18.40	8582	712	19.29	19.25
8338	9987	16.50	16.00	8848	328	15.85	15.02	8503	594	18.40	18.47	8584	722	18.42	18.30
8367	52	17.25	16.74	8858	376	16.77	16.21	8510	656	17.22	16.95	8584	736	17.88	17.61
8366	34	16.63	15.69	8865	303	16.10	15.59	8530	610	17.98	17.75	8589	757	18.84	18.68
8388	43	16.55	15.86	8880	319	16.67	16.00	8525	634	18.46	18.45	8596	764	18.50	18.46
8426	15	14.35	13.05	8890	340	15.41	14.49	8548	595	17.13	16.63	8618	776	16.47	15.40
8404	50	16.04	15.07	8931	402	15.34	14.13	8547	653	17.01	17.20	8631	752	15.59	15.03
8480	68	16.60	16.80	8983	399	17.08	16.62	8550	668	16.89	16.36	8642	691	17.82	17.54
8490	9998	16.11	16.28	8186	415	16.95	16.37	8542	681	17.74	17.34	8657	788	18.20	18.06
8524	36	16.86	16.24	8198	412	17.32	16.92	8556	660	16.31	15.66	8678	722	18.03	17.90
8531	49	15.51	14.49	8227	396	14.94	13.69	8561	635	17.36	16.79	8692	699	18.43	18.26
8534	70	17.10	16.68	8272	387	16.65	15.94	8582	602	16.96	16.30	8692	665	18.18	17.78
8555	20	16.26	15.53	8280	446	17.29	16.81	8584	637	16.23	15.56	8700	717	16.96	16.30
8574	49	16.44	15.50	8353	430	15.44	15.27	8585	657	18.03	17.54	8721	695	15.66	14.75
8577	58	16.86	16.15	8408	423	15.36	15.20	8583	672	15.41	15.30	8734	722	15.00	14.91
8610	25	15.05	14.70	8426	432	16.59	15.83	8616	645	15.57	14.45	8756	719	17.75	16.40
8620	67	16.97	16.42	8445	442	16.70	16.06	8655	593	15.43	15.24	8764	760	17.02	16.78
8639	11	17.04	16.58	8450	441	16.80	16.21	8703	609	16.70	16.02	8790	748	15.81	15.88
8665	27	15.95	15.04	8495	399	16.87	16.24	8704	680	17.13	16.60	8801	734	17.08	16.59
8677	33	15.39	14.39	8574	416	16.00	15.18	8749	650	17.14	16.60	8800	726	16.70	16.11
8677	48	15.00	13.92	8583	479	17.20	16.68	8786	616	16.33	15.68	8944	735	16.66	16.16
8711	9993	16.50	15.90	8654	418	16.45	15.90	8789	634	16.60	16.07	8961	743	15.60	15.67
8712	76	17.13	16.60	8668	394	16.28	15.39	8828	610	14.94	14.77	9031	704	15.87	14.94
8733	46	17.00	16.39	8718	414	15.14	14.86	8832	604	17.07	16.54	8198	845	17.66	17.34
8745	37	16.09	15.17	8752	458	13.26	11.60	8854	612	16.83	16.29	8207	817	18.20	18.00
8743	2	16.40	16.53	8757	452	16.18	15.40	8850	659	13.91	12.67	8205	793	16.95	16.41
8764	22	15.70	14.73	8778	422	17.16	16.57	8861	647	16.76	16.19	8217	788	18.00	17.81
8165	123	15.62	14.52	8856	406	16.62	16.11	8929	693	17.11	16.67	8207	864	19.70	19.27
8215	148	16.58	15.94	8111	521	16.28	15.67	8929	626	17.09	16.60	8303	855	19.37	19.05
8250	170	15.73	14.41	8214	526	16.74	15.78	8935	647	15.68	14.70	8395	794	15.51	14.36
8247	119	15.04	13.95	8256	521	16.79	16.20	8942	663	16.71	16.05	8313	827	19.27	19.02
8405	174	16.65	15.96	8269	530	16.75	16.22	8953	623	16.65	16.19	8316	882	19.67	19.28
8413	106	16.53	15.89	8311	568	17.08	16.62	8955	614	16.29	15.64	8325	790	19.26	19.20
8460	136	16.97	16.45	8410	504	14.10	12.84	8982	661	13.80	12.83	8337	870	19.94	19.39
8508	129	12.59	11.90	8424	559	16.56	15.94	8980	669	17.12	16.47	8357	817	19.90	19.21
8553	159	16.46	15.82	8429	571	15.71	15.60	8168	724	16.60	16.15	8363	808	19.23	19.31
8577	150	16.38	15.50	8458	525	15.25	14.92	8254	751	16.82	16.20	8372	807	19.44	19.14
8610	156	16.60	16.16	8565	557	16.86	16.26	8266	784	19.61	19.21	8381	798	17.96	17.91
8600	91	16.60	16.10	8510	508	14.90	14.12	8304	722	18.65	18.42	8385	808	17.12	16.81
8736	164	15.20	15.01	8515	557	16.65	15.97	8321	752	19.74	19.26	8380	876	18.80	18.83
8763	124	15.16	15.03	8532	558	15.00	14.69	8321	718	19.32	19.13	8390	860	18.23	18.24
8762	116	16.94	16.21	8556	517	15.84	15.05	8327	710	19.13	18.77	8398	877	18.76	18.50
8778	117	15.22	14.92	8575	523	15.57	14.24	8334	708	19.77	19.53	8398	840	19.33	19.06
8779	110	16.44	15.74	8584	578	14.77	13.54	8345	722	15.76	14.81	8395	803	17.37	16.79
8004	191	17.02	16.39	8638	567	16.94	16.37	8356	771	19.61	19.29	8403	808	18.46	18.05
8043	266	17.02	16.41	8637	594	16.80	16.08	8354	753	19.71	19.35	8414	874	17.27	16.60
8603	251	16.91	16.19	8676	515	13.69	11.97	8362	680	18.17	18.06	8420	838	13.14	12.73
8090	281	16.54	15.86	8687	575	16.30	15.69	8377	710	19.22	18.94	8441	798	12.38	11.98
8180	259	15.52	15.25	8715	523	14.98	14.78	8371	739	18.75	18.57	8447	868	17.06	16.52
8226	282	15.18	14.85	8782	585	16.18	15.57	8367	773	18.46	18.26	8463	814	17.67	17.17
8253	190	15.67	14.54	8815	507	17.07	17.55	8369	780	17.64	17.65	8470	874	19.39	18.77
8268	226	13.64	12.03	8846	535	14.91	13.45	8385	774	18.78	18.49	8475	852	17.14	16.60
8290	246	16.07	14.95	8856	557	16.74	16.15	8386	708	18.79	19.46	8477	815	17.93	17.90
8352	226	16.47	15.73	8879	502	16.35	15.54	8391	786	19.50	17.62	8483	840	19.22	18.96
8356	230	16.59	15.78	8881	494	16.52	16.08	8393	768	18.18	17.99	8486	850	19.66	19.05
8395	280	16.10	15.24	8888	503	15.73	14.89	8392	745	16.69	15.31	8491	881	19.37	18.97
8438	189	16.92	16.33	8885	545	16.48	15.84	8398	740	15.78	14.73	8491	811	18.09	17.98
8489	231	15.90	14.96	8906	543	15.33	14.79	8397	733	19.47	18.93	8509	820	19.32	19.08
8514	200	16.49	15.86	8920	511	16.48	15.93	8403	694	18.96	18.36	8511	883	19.89	19.29
8531	235	16.81	16.13	8946	539	15.13	15.25	8403	726	18.86	18.63	8519	878	18.73	18.64
8554	190	15.67	14.93	8958	521	16.80	16.28	8420	704	19.76	19.51	8510	868	18.32	18.22
8549	212	16.56	15.93	8967	504	15.43	14.40	8421	755	19.61	19.11	8515	838	20.00	19.10
8558	230	15.76	14.74	8207	593	16.43	15.05	8441	799	19.15	19.15	8519	834	19.27	19.04
8597	231	17.11	16.70	8218	620	17.25	16.67	8433	711	18.78	18.76	8511	806	18.88	18.59
8597	280	15.99	15.02	8222	608	17.16	16.26	8451	715	18.56	18.45	8530	792	18.56	18.43
8631	275	15.05	14.83	8261	637	17.29	16.79	8449	750	18.00	17.89	8528	827	18.32	18.23
8665	235	16.66	16.05	8311	617	15.58	14.54	8452	743	16.80	16.41	8538	879	18.12	17.53
8730	211	16.90	16.21	8393	677	19.70	19.14	8466	690	19.97	19.54	8535	826	19.23	18.96
8779	196	17.00	16.50	8402	683	17.88	17.72	8467	767	19.73	19.09	8542	857	17.61	17.20
7999	297	16.57	16.03	8400	626	19.19	18.76	8472	738	19.58	19.39	8543	864	18.10	17.71
8141	324	16.26	15.57	8400	617	19.92	19.33	8488	690	17.98	17.71	8543	884	18.44	18.32
8334	300	13.88	12.44	8366	595	18.90	18.62	8486	708	18.47	18.28	8551	861	19.35	19.01
8377	302	15.33	15.05	8409	598	18.01	18.04	8489	723	19.97	19.55	8553	840	18.60	18.33
8379	334	16.41	15.48	8403	648	19.66	19.20	8489	771	18.21	18.20	8551	806	17.34	16.81
8404	372	16.61	15.97	8420	637	19.									

TABLE III (continued)

X	Y	B	V	X	Y	B	V	X	Y	B	V	X	Y	B	V
8765	792	15.96	14.66	8369	924	18.42	18.23	8558	985	17.40	16.92	8449	1071	18.44	18.21
8776	834	16.11	15.45	8388	940	19.85	19.31	8568	977	18.80	18.63	8452	1082	19.45	19.33
8773	810	16.22	15.56	8382	910	18.78	18.75	8581	920	18.52	17.89	8466	1035	16.24	15.19
8846	834	15.41	15.39	8402	973	18.54	17.44	8602	932	17.99	17.40	8490	992	9.86	8.59
8880	844	15.12	15.17	8399	935	18.01	17.72	8608	934	17.27	16.81	8507	1070	14.67	13.84
8805	862	15.80	15.94	8404	902	18.03	17.72	8611	951	16.99	16.55	8522	1007	17.54	17.07
8907	840	17.07	16.54	8412	965	19.76	19.19	8687	902	16.47	15.80	8526	1088	18.13	17.87
8984	856	15.36	15.44	8420	979	19.45	19.17	8709	910	17.48	16.87	8540	1034	17.13	16.60
8999	876	16.37	15.70	8428	895	17.59	17.19	8701	913	16.51	15.90	8551	1064	17.22	16.59
9040	810	15.80	15.10	8430	931	15.37	15.24	8709	982	11.26	10.10	8581	1008	16.95	16.43
9046	815	16.48	15.82	8435	946	16.77	16.10	8731	912	16.56	15.74	8598	1018	17.98	17.66
8192	922	17.55	17.06	8437	987	19.30	18.82	8746	931	12.77	11.20	8598	1002	17.83	17.64
8203	958	14.45	13.67	8444	982	16.89	16.43	8765	911	17.32	16.41	8610	1068	16.26	15.44
8251	917	18.13	17.92	8441	918	19.49	19.19	8772	981	17.57	17.18	8624	1064	18.38	18.27
8257	973	18.26	18.20	8450	931	17.14	16.37	8786	978	15.24	14.48	8642	1013	17.12	16.63
8294	905	18.80	18.60	8452	963	18.99	18.73	8798	987	16.95	16.32	8651	1051	18.24	17.72
8294	911	18.75	18.66	8473	915	19.20	19.08	8848	907	13.88	13.03	8682	1066	17.66	17.02
8400	931	18.52	17.70	8473	923	17.56	17.16	8841	948	16.80	16.45	8702	1034	16.02	15.32
8302	897	15.22	14.93	8492	912	18.07	17.80	8855	944	15.25	14.42	8827	1029	16.75	13.86
8313	880	19.31	19.08	8491	900	19.73	19.27	8848	976	16.64	15.96	8858	1017	16.40	15.85
8310	942	19.20	18.85	8501	893	19.44	19.02	8892	977	16.37	15.81	8434	1131	18.19	17.86
8313	984	17.44	16.71	8522	906	19.25	18.87	8988	982	16.46	15.81	8434	1102	18.50	18.29
8322	953	18.21	18.14	8525	944	18.38	17.78	8299	1030	18.05	17.76	8469	1120	17.97	17.62
8321	946	19.88	19.23	8538	934	19.37	19.04	8321	1002	16.61	15.93	8511	1163	18.27	18.18
8321	906	18.87	18.56	8531	906	18.56	18.29	8357	1063	18.06	17.67	8520	1135	14.35	13.49
8333	950	18.33	18.25	8544	942	19.52	19.09	8388	1035	19.61	19.27	8559	1150	17.10	16.45
8350	905	19.77	19.42	8550	903	18.63	18.47	8389	1024	18.93	17.66	8566	1171	16.22	15.53
8399	891	18.50	17.91	8557	897	18.19	18.05	8409	1069	17.34	15.90	8578	1122	17.19	16.20
8370	917	18.64	18.40	8559	952	19.60	19.28	8418	1047	18.78	18.69	8578	1131	17.20	16.70

Figure 2 shows the color-magnitude diagram of ω Cen, based on the magnitudes of Table III. The sudden change in density near the seventeenth magnitude is simply the result of the

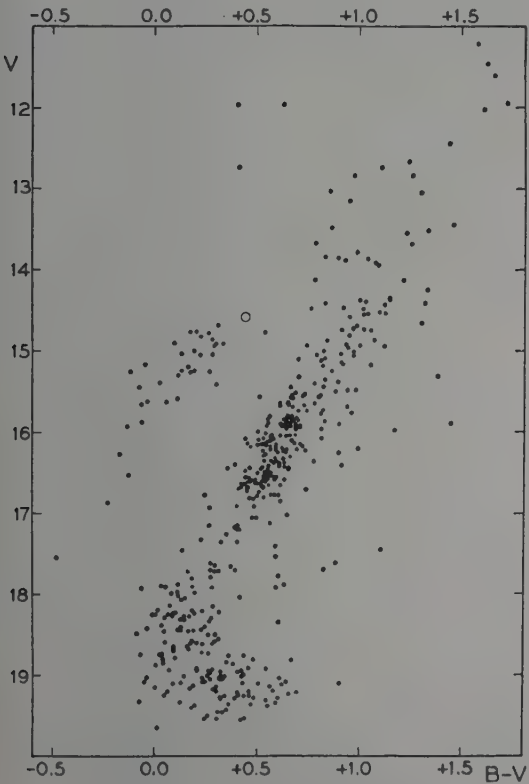


Figure 2. Color-magnitude diagram.

transition from region I to region II which is one-fourth as large and also centered further out in the cluster; it contains about one-fifth as many stars as region I. The transition from region II to region III, involving a factor of two-fifths, was made at $V = 17.5$; it is not conspicuous. The open circle indicates the position of the RR Lyrae variables according to the average magnitude of 13 stars on plate B2, $B = 15.02$, and of the same stars on plates V2 and V3, $V = 14.58$. Figure 2 exhibits the familiar features that have been observed in other globular clusters, and it is particularly reminiscent of M13. There are the isolated blue stars, the red giants merging with a sub-giant sequence in which color index decreases with increasing magnitude, and, finally, a knee below which the color index increases with increasing magnitude. The position of this knee in ω Cen is quite doubtful because of the low systematic accuracy of the magnitude scales at the faint end. Perhaps even its reality can be called into question. It is possible, although it does not seem likely, that the magnitude scales depart enough from linearity in this region to introduce a spurious curvature in the color-magnitude diagram. The red giants scatter widely in Figure 2 instead of defining what might properly be called a branch; attention is called to the fact that the field error has its greatest effect on the brightest stars.

It is the central part of the diagram, around magnitudes 15, 16 and 17, that is least affected by the photometric uncertainties; in this magnitude range it is possible to make a quantitative comparison of ω Cen with other clusters. This is

done in Figure 3 where the principal sequences of ω Cen, M3, and M13 are represented schematically by heavy, light, and broken lines, respectively. The coordinates are color and magnitude in ω Cen. The sequences from M3 (Johnson and Sandage 1956) and M13 (Baum 1954, Arp and Johnson 1955) have been brought into the same part of the color-magnitude plane by shifts in both coordinates of such an amount as will bring the tops of the blue sequences together. This is an arbitrary procedure but it has the advantage of fixing a well-defined point from which to measure color and magnitude differences. The point chosen has the additional advantage of being adjacent to the RR Lyrae variables. If these stars have the same intrinsic color and magnitude in the different clusters then the reduction of the coordinates of Figure 3 to absolute magnitude and intrinsic color is simply one of translation by very nearly the same amount for the three

clusters. M92 has been omitted from Figure 3 to avoid too complex an appearance. If it were included its giants, sub-giants, and main sequence would all, as is well known (Sandage 1953), fall to the blue of the schematic sequence for M3, by about 0.15 mag.

No attempt has been made to draw a schematic giant branch for ω Cen and it is not possible to compare the colors of its giants with the other clusters on the basis of the magnitudes in this paper. Similarly, one hesitates to compare the position of the knees until there are more photoelectric magnitudes of faint stars. To take Figure 3 at its face value would imply that the faintest stars observed in ω Cen occupy the same portion of the color-magnitude plane as the main sequence in M13, with the difference that in ω Cen the sequence which the two clusters seem to share is populated to a brighter magnitude. Recent observations in M13 (Johnson 1958), however, suggest that the main sequence as given by Baum (1954) and plotted in Figure 3 may be about one magnitude too faint.

At the intermediate magnitudes where one can compare the clusters with more confidence, ω Cen is seen to be qualitatively similar to M13 in that both have sloping sub-giant sequences without a vertical section, but the slope in ω Cen is much less steep. These stars become a good deal bluer, relative to the upper branches, than in other clusters yet observed. Already at the seventeenth magnitude the stars in ω Cen are 0.4 mag. bluer than those in M3. They are, in fact, as blue as the RR Lyrae stars. It is doubtful that a difference as large as this can be attributed entirely to uncertainties in the photometric process.

A luminosity function has also been derived from this program, specifically from the star counts which are listed in Table IV. $N^I(m)$ is the number of stars in region I brighter than m , etc. $A(m)$ is the number per square degree between $m - 1/2$ and $m + 1/2$, corrected statistically for the galactic contribution (Seares *et al.* 1925), at a distance of 16'.4 from the center of the cluster, i.e., at the distance of region II. The counts include not only the stars in Table III, but also the remaining stars on the program whether their magnitudes have been based on measures or estimates. In the immediate vicinity of the brightest stars, however, neither measures nor estimates of magnitude have much meaning; small circular regions surrounding these bright stars have, therefore, been omitted from the counting program.

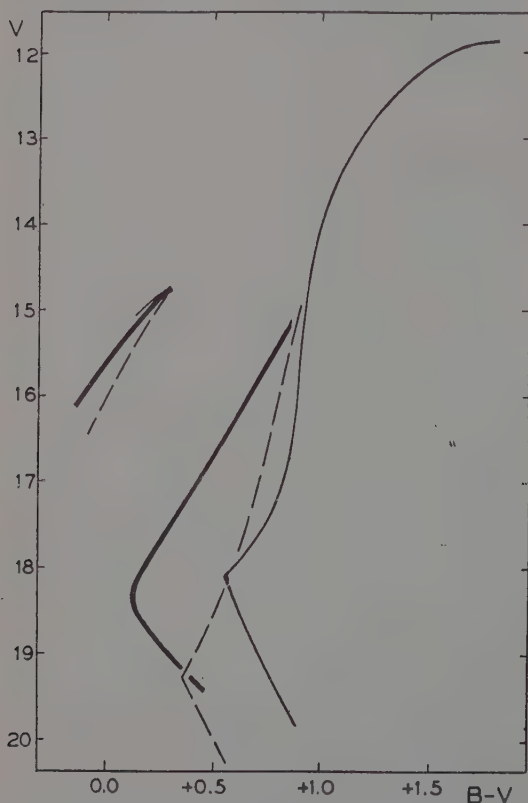


Figure 3. Comparison of the color-magnitude relations in ω Cen (heavy line), M3 (light line) and M13 (dashed line).

TABLE IV. LUMINOSITY FUNCTIONS

B or V	N ^I (B)	N ^{II} (B)	N ^{III} (B)	Log A(B)	N ^I (V)	N ^{II} (V)	N ^{III} (V)	Log A(V)
11.0	1	1	0		3	2	0	
11.5	3	2	0	1.76	5	4	1	2.04
12.0	3	2	0		7	4	1	
12.5	4	3	1	1.82	11	5	2	2.36
13.0	6	4	1		16	6	3	
13.5	9	6	3	2.42	18	7	4	2.39
14.0	16	6	3		29	11	5	
14.5	21	7	4	2.69	40	12	6	3.11
15.0	36	12	5		79	19	9	
15.5	75	18	8	3.34	115	26	13	3.34
16.0	111	22	11			38	14	
16.5	162	32	13	3.54		52	19	3.60
17.0		47	19			74	28	
17.5		75	30	3.94		96	37	3.98
18.0		108	46			154	62	
18.5		209	97	4.68		268	121	4.71
19.0		389	169			476	212	
19.5			256	4.86			382	5.06
20.0			357				518	
Area (min ²)	84.9	19.0	8.4					

To derive the spatial density one needs to know the law of decrease of density with increasing distance, from 16'.4 outward. In the outer parts of globular clusters the projected density is very nearly inversely proportional to the cube of the distance and the spatial density, therefore, inversely proportional to the fourth power (Jeans 1916). Other analytic forms have sometimes been used, but this simple one is quite adequate, and is quite closely obeyed by the integrated light in ω Cen according to the observations of Gascoigne and Burr (1956). In this case the number of stars in a cube whose sides subtend 1' is $2A(m)/\pi r$, where r is the angular distance in minutes from the center of the cluster. The conversion from angular to linear measure requires a knowledge of the modulus and absorption, but, as we shall see, it is not very sensitive to the adopted values. Let us adopt, as the photovisual modulus, 14.75, the magnitude of the top of the blue branch, and take the photovisual absorption to be 0.6. This is a rather small value for such a low galactic latitude; it is suggested by the fact that the blue stars in ω Cen are less than 0.2 mag. redder than those in M3, and by Shapley's (1944) observation that the nebular counts are consistent with a differential absorption of only 0.5 mag., photographic, between the field of ω Cen and the galactic poles. With these assumptions, the luminosity function $\Phi(M)$, i.e., the number of stars per cubic parsec between absolute magnitude $M - 1/2$ and $M + 1/2$, assumes the values plotted in Figure 4, where the upper curves refer to ω Cen; the lower curves are the galactic den-

sities according to van Rhijn (1936). In the well-observed central sections, from absolute magnitude -1 to $+3$ according to the assumed modulus, the slope is about 0.4 in both colors, quite similar to the slope of the galactic functions in the same range. This similarity of slope enables us to assign a representative value to the ratio of the stellar density in the cluster to that in the neighborhood of the sun, more or less independent of the magnitudes of the stars. The difference in the ordinate is about 1.4, which means that even at 16'.4 from the center the stellar density is 25 times as great as in the neighborhood of the sun. The ratio approaches 100 for fainter and brighter stars, but it is not so well determined there. According to Gascoigne and Burr (1956), there is 1000 times as much light emitted per cubic parsec at the center than at this distance. We estimate, then, that the stellar density is 25,000 times as great at the center of ω Cen as in the solar neighborhood, or that the average distance between stars is about one-thirtieth as great. That this density must be correct as to order of magnitude appears from the following considerations. The upper curves have been drawn for a photovisual modulus of 14.75. A change to a modulus of 15.75 will cause these curves to slide in the direction indicated by the arrow (Schilt *et al.* 1955). This would in turn decrease the average vertical distance between curves by 0.2. It would take an increase of 1.5 mag. in the modulus to decrease the derived density ratio by a factor two. The result is somewhat more sensitive to the absorption, which affects

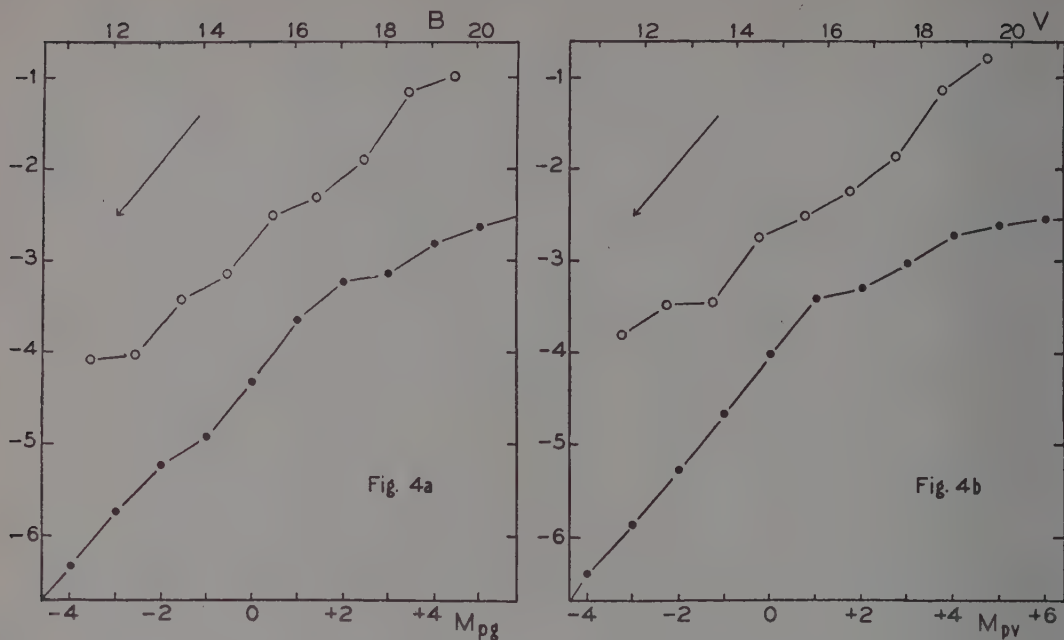


Figure 4. Luminosity function of ω Cen (open circles) and the neighborhood of the sun (dots); (a) photographic; (b) visual. The ordinate is $\log \Phi$.

the derived distance without affecting the photometric modulus. Still it would require a decrease of 0.5 in the assumed absorption to decrease the derived density by a factor two.

The measures of Gascoigne and Burr also show that the light of the whole cluster is 10,000 times as great as the projected light per min^2 at 16'. There are 50 stars per min^2 brighter than $V = 20$ at this distance from the center. We can estimate, then, that there are 500,000 stars in the whole cluster to this same limit, absolute magnitude +5.3 according to the assumed modulus. This may be compared with values near 20,000 for the average cluster (Shapley 1930), specifically, 32,000 in M3 (Sandage 1957).

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and established the photoelectric sequences. In the photographic photometry I had the benefit of advice and assistance from Dr. I. Epstein. Publication expenses have been defrayed by a contribution from the Ernest Kempton Adams Fund for Physical Research.

REFERENCES

- Arp, H. C. 1958, *A. J.* **63**, 118.
 Arp, H. C. and Johnson, H. L. 1955, *Ap. J.* **122**, 171.
 Baum, W. A. 1954, *A. J.* **59**, 422.
 Gascoigne, S. C. B. and Burr, E. J. 1956, *M. N.* **116**, 570.
 Jeans, J. H. 1916, *M. N.* **76**, 567.
 Johnson, H. L. 1958, *Sky and Telescope* **17**, 558.
 Johnson, H. L. and Sandage, A. R. 1956, *Ap. J.* **124**, 379.
 Martin, W. C. 1938, *Ann. Stw. Leiden* **17**, Part II.
 Sandage, A. R. 1953, *A. J.* **58**, 61.
 —, 1957, *Ap. J.* **125**, 422.
 Schilt, J., Epstein, I. and Hill, S. J. 1955, *A. J.* **60**, 341.
 Seares, F. H., van Rhijn, P. J., Joyner, M. C. and Richmond, M. L. 1925, *Ap. J.* **62**, 320.
 Shapley, H. 1930, *Star Clusters*, Harvard Obs. Monograph No. 2 (New York: McGraw-Hill), p. 201.
 —, 1944, *Proc. Nat. Acad. Sci.* **30**, 61.
 van Rhijn, P. J. 1936, *Pub. Astr. Lab. Groningen*, No. 47.

PHOTOELECTRIC LIGHT CURVES OF V566 OPHIUCHI AND AB ANDROMEDAE

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Abstract. Photoelectric observations are presented of two W Ursae Majoris systems; these comprise 363 yellow and 358 blue magnitudes of V566 Ophiuchi, and 391 yellow and 390 blue magnitudes of AB Andromedae. The eccentricity effect in Fresa's observations of V566 Ophiuchi is not confirmed but traced back to a period which was not completely correct. The period of AB Andromedae shows a considerable change since Oosterhoff's photographic observations. The light in the maxima of both stars shows a reflection effect ($\cos \theta$ term), which has a sign opposite that expected by theory.

V566 Ophiuchi. This variable was discovered by C. Hoffmeister (1935, 1943) and observed by V. P. Tsesevich (1950, 1954). Photoelectric observations made without filter were published by A. Fresa (1954), who found a small eccentricity effect in his light curve.

This system was observed photoelectrically during 12 nights during the summers of 1955 and 1957. The 28-inch reflecting telescope of the Flower and Cook Observatory at Paoli was used. The observations were made with a 1P21 photomultiplier, the output of this cell being fed into a direct current amplifier of the Kron type, and the amplified current recorded by a Brown recorder. The duration of each observation was taken as one minute. A yellow filter, Corning 3384 of thickness 3.0 mm was used, having an effective wave length of 5300 Å. The combination Corning 5543 of thickness 2.5 mm and Corning 3060 of thickness 2.0 mm was used for the blue filter, having an effective wave length of 4420 Å. During these nights, 363 yellow and 358 blue magnitudes were obtained.

Table I gives the BD number, the position of the stars, and the spectrum of the variable according to N. G. Roman (1956), while the other spectral types are taken from the HD catalogue. The check star was measured about every two hours during the observations and showed a constant magnitude difference with the comparison star.

TABLE I. VARIABLE AND COMPARISON STARS				
Star	BD No.	R.A. (1900)	D. (1900)	Sp.
V566 Oph	+5°3547	17 ^h 51 ^m 57 ^s	+5°00'0	F4V
comp. star	+4 3553	17 51 17	+4 50.7	K2
check star	+4 3556	17 51 49	+4 23.4	B9

It was not necessary to apply a correction for differential extinction. The times of minima were computed according to the method of E. Hertzsprung (1928) and are listed in Table II. In Fresa's publication geocentric Julian Days are given. The light-time correction was applied to make these data heliocentric. The times of his

minima were computed according to the same method and are given in the same table. In addition two times of minima determined by K. Kwee (1958) from photoelectric observations are used. A least-squares solution gives:

$$\begin{array}{rcl} \text{Min. I} & = & 2435245.5440 + 0.40964101 E \\ & \pm & \text{I} \pm \hspace{1.5cm} 5 \text{ (p.e.)} \end{array}$$

These elements supersede those mentioned by Kwee.

Table III gives the observations in heliocentric Julian Day, phase counted from primary minimum, and the magnitude difference. Table IV and Figure 1 give the normal points after adding .380 to the yellow and .950 to the blue magnitudes to make the magnitude differences zero at maximum. Fresa's data were treated in the same way using our period. His normal points are shown in the same figure and show a good agreement with our blue observations. The secondary minimum is exactly half way between the primary minima and there is no trace of an eccentricity effect. In addition the color curve is given. For these systems where the light is continuously changing it is imperative to compute the difference of the blue and yellow magnitude at exactly the same time or phase, and if necessary correct one of the magnitudes for this effect. In this case the color curve is unusually flat during secondary minimum and shows some reddening during primary minimum.

TABLE II. TIMES OF MINIMA AND RESIDUALS OF V566 OPHIUCHI				
J. D. $\odot$	Min.	Epoch	O - C	Obs.
2434179.45335	II	-2602.5	^d 0000	F
4181.50086	II	2597.5	- 6	F
4226.35716	I	2488	0	F
4237.41775	I	2461	+ 2	F
4515.56393	I	1782	+ 2	K
4593.39559	I	-1592	0	K
5245.74938	II	+ 0.5	+ 5	B
5968.76551	II	1765.5	+ 3	B
5987.81291	I	1812	- 6	B
6010.75340	I	+1868	0	B

F = Fresa, K = Kwee, B = Binnendijk.

TABLE IIIA. YELLOW OBSERVATIONS OF V566 OPHIUCHI

JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm
5243.7262	.5626	-.061	5983.7620	.1095	-.199	6010.7506	.9932	+ .094	6022.6346	.0038	+ .080
.7318	.5761	.119	.7635	.1132	.202	.7520	.9966	.089	.6361	.0075	.089
.7359	.5860	.142	.7648	.1166	.227	.7576	.0102	.078	.6374	.0108	.089
.7414	.5966	.162	.7703	.1209	.244	.7592	.0141	.088	.6388	.0142	.087
.7450	.6008	.166	.7718	.1335	.257	.7608	.0181	.004	.6401	.0174	+ .087
.7490	.6202	.270	.7732	.1369	.262	.7678	.0351	.059	.6533	.0496	-.024
5246.7208	.8728	-.253	.7746	.1403	.274	.7708	.0424	.030	.6548	.0532	.024
.7222	.8762	.261	.7800	.1536	.298	.7744	.0512	+ .020	.6561	.0563	.031
.7263	.8861	.214	.7814	.1570	.306	.7812	.0678	-.003	.6576	.0600	.033
.7278	.8898	.216	.7828	.1604	.311	.7826	.0712	.084	.6637	.0750	.105
.7332	.9031	.186	.7842	.1638	.315	.7842	.0752	.114	.6652	.0787	.110
.7340	.9065	.160	.7897	.1773	.328	.7856	.0786	.124	.6666	.0821	.128
.7388	.9166	.133	.7912	.1810	.338	6020.7408	.3809	-.240	.6680	.0855	.119
.7403	.9203	.126	.7926	.1844	.340	.7422	.3843	.234	.6734	.0987	.168
.7457	.9336	.100	.7940	.1878	.346	.7441	.3888	.217	.6749	.1024	.197
.7472	.9373	.086	.7995	.2011	.358	.7510	.4058	.174	.6763	.1058	.179
.7521	.9491	.042	.8008	.2045	.363	.7526	.4097	.149	.6777	.1092	.196
.7535	.9525	-.026	.8023	.2081	.377	.7543	.4137	.138	.6832	.1225	.237
.7590	.9661	+ .060	.8037	.2115	.371	.7590	.4179	.141	.6847	.1261	.235
.7604	.9695	.067	5987.6836	.6829	-.350	.7617	.4317	.099	.6861	.1295	.253
.7646	.9796	.076	.6850	.6863	.347	.7633	.4357	.081	.6874	.1329	.256
.7660	.9830	.083	.6865	.6900	.358	.7649	.4397	.060	.6920	.1462	.302
.7715	.9966	.091	.6878	.6931	.348	.7714	.4555	.010	.6944	.1499	.300
.7729	.0000	.076	.6933	.7066	.352	.7729	.4591	-.003	.6958	.1533	.287
.7770	.0099	.094	.6958	.7126	.351	.7743	.4625	+ .011	.6972	.1587	.290
.7785	.0135	.089	.6973	.7163	.379	.7764	.4676	.017	.7006	.1696	.316
.7849	.0271	.070	.6989	.7202	.355	.7832	.4843	.036	.7041	.1735	.324
.7854	.0305	.063	.7045	.7338	.366	.7848	.4883	.030	.7055	.1770	.343
.7866	.0407	.041	.7058	.7372	.381	.7864	.4922	.045	.7068	.1801	.346
.7910	.0441	+ .027	.7073	.7408	.379	.7880	.4962	+ .028	.7227	.2191	.367
5348.5824	.5334	-.002	.7086	.7439	.387	6021.0318	.5559	-.033	.7242	.2228	.370
.5927	.5585	.045	.7142	.7575	.375	.6333	.5596	.056	.7256	.2262	.371
.5968	.5687	.083	.7156	.7609	.371	.6347	.5630	.063	.7270	.2295	.374
.6024	.5822	.119	.7171	.7646	.375	.6361	.5663	.071	6027.6421	.2280	-.378
.6066	.5924	.155	.7433	.8287	.317	.6415	.5796	.017	.6435	.2314	.351
.6121	.6060	.190	.7447	.8321	.320	.6430	.5833	.144	.6448	.2347	.380
.6163	.6161	.216	.7462	.8358	.306	.6444	.5867	.150	.6462	.2381	.362
.6205	.6263	.253	.7483	.8408	.327	.6458	.5901	.155	.6573	.2653	.376
5968.7316	.4180	-.144	.7538	.8541	.288	.6512	.6034	.209	.6587	.2686	.351
.7335	.4225	.104	.7505	.8609	.281	.6527	.6070	.204	.6601	.2720	.386
.7352	.4268	.106	.7580	.8646	.281	.6541	.6104	.215	.6615	.2754	.382
.7367	.4304	-.084	.7594	.8680	.274	.6555	.6138	.227	.6629	.2791	.336
.7510	.4052	+ .014	.7650	.8816	.238	.6610	.6271	.261	.6704	.2972	.349
.7526	.4091	.034	.7665	.8852	.223	.6623	.6305	.265	.6719	.3008	.338
.7541	.4728	.030	.7680	.8889	.210	.6637	.6339	.269	.6733	.3042	.345
.7550	.4765	.041	.7693	.8920	.210	.6651	.6373	.272	.6789	.3178	.317
.7620	.4926	.036	.7740	.9080	.172	.6714	.6525	.275	.6803	.3212	.316
.7636	.4960	.027	.7761	.9084	.165	.6729	.6562	.268	.6818	.3249	.313
.7652	.4999	.036	.7775	.9120	.161	.6743	.6596	.301	.6830	.3280	.309
.7668	.5039	.043	.7789	.9154	-.138	.6759	.6630	.300	.6863	.3433	.296
.7725	.5177	.052	.7921	.9470	+ .013	.6866	.6868	.336	.6908	.3469	.277
.7740	.5214	.041	.7935	.9511	.011	.6882	.6935	.350	.6921	.3501	.281
.7756	.5253	.037	.7948	.9544	.019	.6895	.6966	.354	.6936	.3537	.273
.7772	.5293	+ .040	.7961	.9575	.032	.6909	.7003	.359	.6961	.3673	.260
.7830	.5435	-.001	.8010	.9694	.068	.6964	.7136	.359	.7008	.3713	.246
.7846	.5474	.021	.8025	.9731	.054	.6979	.7172	.359	.7021	.3740	.228
.7863	.5514	.022	.8038	.9762	.074	.6993	.7206	.369	.7034	.3777	.239
.7879	.5553	.016	.8053	.9799	.072	.7006	.7240	.360	.7087	.3907	.206
.7947	.5720	.105	.8107	.9931	.092	.7075	.7407	.369	.7102	.3944	.199
.7962	.5757	.105	.8121	.9965	.095	.7090	.7444	.380	.7115	.3975	.195
.7978	.5796	.121	.8135	.9999	.072	.7104	.7478	.376	.7129	.4009	.184
.7995	.5836	.121	.8145	.0024	.084	.7118	.7511	.382	.7185	.4145	.132
.8051	.5974	.180	.8204	.0169	.092	.7172	.7644	.367	.7200	.4181	.132
.8066	.6011	.189	.8219	.0205	.081	.7187	.7681	.367	.7212	.4212	.120
.8082	.6050	.185	.8232	.0237	.077	.7200	.7712	.377	.7226	.4246	.102
.8099	.6090	.199	.8247	.0273	+ .065	.7217	.7754	.377	.7283	.4385	.050
5983.6953	.9468	-.055	.8357	.0542	-.013	.7277	.7901	.360	.7297	.4419	.048
.6967	.9502	-.027	.8372	.0578	.025	.7291	.7935	.363	.7310	.4450	.035
.6982	.9538	+ .037	.8386	.0612	.036	.7305	.7969	.359	.7323	.4484	-.021
.6996	.9572	.037	.8399	.0643	.051	.7319	.8003	.370	.7435	.4755	+ .045
.7058	.9725	.078	6010.6875	.8300	- .310	.7429	.8271	.345	.7448	.4789	.045
.7071	.9756	.088	.6880	.8426	.312	.7500	.8444	.301	.7462	.4823	+ .040
.7085	.9790	.079	.6907	.8460	.320	.7513	.8478	.293	6035.6765	.8414	-.312
.7099	.9824	.066	.6923	.8508	.296	.7527	.8512	.281	.6770	.8448	.316
.7154	.9960	.076	.7062	.8848	.198	.7541	.8546	.279	.6793	.8482	.316
.7169	.9996	.083	.7078	.8887	.207	.7596	.8678	.263	.6807	.8516	.312
.7182	.0027	.089	.7094	.8926	.205	.7610	.8712	.247	.6925	.8804	.217
.7197	.0064	.087	.7110	.8966	.201	.7623	.8746	.244	.6930	.8838	.213
.7253	.0200	.085	.7173	.9119	.122	.7638	.8783	.250	.6954	.8875	.214
.7266	.0233	.063	.7189	.9158	.125	.7694	.8918	.205	.6967	.8906	.206
.7279	.0265	.079	.7205	.9198	.104	.7707	.8950	.201	.7043	.9092	.152
.7294	.0301	.067	.7222	.9237	.097	.7723	.8989	.179	.7057	.9126	.148
.7350	.0437	.028	.7284	.9390	.031	.7730	.9020	.182	.7078	.9177	.119
.7363	.0468	+ .003	.7300	.9429	.029	6022.6089	.9411	-.027	.7093	.9214	- .131
.7376	.0502	-.017	.7316	.9469	-.016	.6104	.9447	-.004	.7293	.9703	+ .073
.7391	.0539	.046	.7333	.9508	+ .024	.6117	.9481	+ .011	.7308	.9740	.097
.7453	.0689	.076	.7388	.9644	.082	.6131	.9515	.007	.7329	.9790	.080
.7468	.0725	.095	.7402	.9678	.075	.6186	.9648	.055	.7343	.9824	.078
.7482	.0759	.105	.7418	.9718	.071	.6201	.9685	.057	.7399	.9960	.072
.7496	.0793	.115	.7479	.9865	.100	.6215	.9719	.067	.7412	.9994	+ .073
.7607	.1064	-.202	.7494	.9901	+ .086	.6229	.9752	+ .078			

TABLE IIIb. BLUE OBSERVATIONS OF V566 OPHIUCHI

JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm
5243.7269	.5643	-.654	5983.7626	.1112	-.757	6010.7599	.0159	-.477	6023.6352	.0055	-.459
.7325	.5778	.695	.7641	.1149	.781	.7622	.0215	.493	.6366	.0089	.468
.7365	.5877	.709	.7655	.1183	.795	.7685	.0367	.513	.6381	.0126	.464
.7424	.6021	.769	.7710	.1316	.812	.7715	.0441	.495	.6395	.0160	.467
.7463	.6115	.770	.7724	.1350	.822	.7736	.0492	.523	.6406	.0185	.461
.7504	.6216	.846	.7739	.1386	.833	.7749	.0526	.555	.6540	.0512	.571
5246.7215	.8745	-.809	.7752	.1417	.847	.7819	.0695	.652	.6554	.0546	.603
.7229	.8779	.818	.7807	.1553	.872	.7833	.0729	.647	.6568	.0580	.603
.7271	.8881	.773	.7821	.1587	.874	.7849	.0769	.686	.6582	.0614	.617
.7285	.8915	.764	.7835	.1621	.892	.7863	.0803	.681	.6644	.0767	.601
.7340	.9051	.730	.7849	.1655	.888	.7904	.1790	.906	.6658	.0801	.705
.7354	.9084	.715	.7904	.1790	.906	.7918	.1824	.909	.6672	.0835	.715
.7396	.9186	.684	.7932	.1858	.911	.7946	.1892	.913	.6686	.0869	.699
.7410	.9220	.664	.7946	.1892	.913	.8001	.2027	.936	.6741	.1004	.744
.7465	.9355	.637	.8001	.2027	.936	.8015	.2061	.939	.6755	.1038	.704
.7479	.9390	.623	.8015	.2061	.939	.8030	.2098	.951	.6769	.1072	.752
.7528	.9508	.585	.8030	.2098	.951	.8044	.2132	.945	.6783	.1106	.761
.7542	.9542	.562	.8044	.2132	.945	.8057	.2166	.941	.6838	.1241	.793
.7597	.9678	.490	.8057	.2166	.941	.8071	.2200	.936	.6852	.1275	.814
.7611	.9712	.487	.8071	.2200	.936	.8085	.2234	.931	.6866	.1309	.829
.7652	.9811	.461	.8085	.2234	.931	.8099	.2268	.926	.6880	.1342	.837
.7667	.9847	.467	.8099	.2268	.926	.8113	.2302	.921	.6894	.1376	.888
.7722	.9983	.478	.8113	.2302	.921	.8127	.2336	.916	.6908	.1410	.884
.7736	.0017	.477	.8127	.2336	.916	.8141	.2370	.911	.6922	.1444	.876
.7778	.0118	.458	.8141	.2370	.911	.8155	.2404	.906	.6936	.1478	.883
.7791	.0150	.466	.8155	.2404	.906	.8169	.2438	.901	.6950	.1512	.876
.7847	.0288	.479	.8169	.2438	.901	.8183	.2472	.896	.6964	.1546	.883
.7860	.0319	.484	.8183	.2472	.896	.8197	.2506	.891	.6978	.1580	.880
.7903	.0424	.511	.8197	.2506	.891	.8211	.2540	.886	.6992	.1614	.904
.7916	.0455	.509	.8211	.2540	.886	.8225	.2574	.881	.7006	.1648	.909
5348.5871	.5450	-.548	.8225	.2574	.881	.8239	.2608	.876	.7020	.1682	.926
.5934	.5602	.639	.8239	.2608	.876	.8253	.2642	.871	.7034	.1716	.922
.5977	.5707	.603	.8253	.2642	.871	.8267	.2676	.866	.7048	.1750	.904
.6031	.5840	.704	.8267	.2676	.866	.8281	.2710	.861	.7062	.1784	.909
.6074	.5944	.748	.8281	.2710	.861	.8295	.2744	.856	.7076	.1818	.926
.6129	.6080	.787	.8295	.2744	.856	.8309	.2778	.851	.7090	.1852	.928
.6170	.6179	.798	.8309	.2778	.851	.8323	.2812	.846	.7104	.1886	.938
.6211	.6280	.840	.8323	.2812	.846	.8337	.2846	.841	.7118	.1920	.942
5968.7323	.4197	-.678	.8337	.2846	.841	.8351	.2880	.836	.7132	.1954	.940
.7342	.4242	.657	.8351	.2880	.836	.8365	.2914	.831	.7146	.1988	.946
.7358	.4282	.658	.8365	.2914	.831	.8379	.2948	.826	.7160	.2022	.932
.7375	.4324	.631	.8379	.2948	.826	.8393	.2982	.821	.7174	.2056	.931
.7376	.4366	.533	.8393	.2982	.821	.8407	.3016	.816	.7188	.2090	.900
.7533	.4708	.519	.8407	.3016	.816	.8421	.3050	.811	.7202	.2124	.876
.7548	.4745	.533	.8421	.3050	.811	.8435	.3084	.806	.7216	.2158	.883
.7563	.4782	.522	.8435	.3084	.806	.8449	.3118	.801	.7230	.2192	.876
.7626	.4937	.498	.8449	.3118	.801	.8463	.3152	.796	.7244	.2226	.882
.7643	.4977	.519	.8463	.3152	.796	.8477	.3186	.791	.7258	.2260	.864
.7659	.5010	.519	.8477	.3186	.791	.8491	.3220	.786	.7272	.2294	.867
.7675	.5056	.530	.8491	.3220	.786	.8505	.3254	.781	.7286	.2328	.859
.7731	.5191	.531	.8505	.3254	.781	.8519	.3288	.776	.7300	.2362	.832
.7747	.5231	.514	.8519	.3288	.776	.8533	.3322	.771	.7314	.2396	.849
.7764	.5273	.515	.8533	.3322	.771	.8547	.3356	.766	.7328	.2430	.847
.7780	.5313	.515	.8547	.3356	.766	.8561	.3390	.761	.7342	.2464	.834
.7838	.5454	.575	.8561	.3390	.761	.8575	.3424	.756	.7356	.2498	.809
.7853	.5491	.585	.8575	.3424	.756	.8589	.3458	.751	.7370	.2532	.786
.7870	.5530	.587	.8589	.3458	.751	.8603	.3492	.746	.7384	.2566	.789
.7886	.5570	.571	.8603	.3492	.746	.8617	.3526	.741	.7398	.2600	.765
.7953	.5734	.680	.8617	.3526	.741	.8631	.3560	.736	.7412	.2634	.759
.7969	.5773	.670	.8631	.3560	.736	.8645	.3594	.731	.7426	.2668	.768
.7985	.5813	.689	.8645	.3594	.731	.8659	.3628	.726	.7440	.2702	.746
.8001	.5853	.677	.8659	.3628	.726	.8673	.3662	.721	.7454	.2736	.683
.8057	.5988	.746	.8673	.3662	.721	.8687	.3696	.716	.7468	.2770	.696
.8073	.6028	.759	.8687	.3696	.716	.8701	.3730	.711	.7482	.2804	.667
.8090	.6070	.764	.8701	.3730	.711	.8715	.3764	.706	.7496	.2838	.644
.8105	.6107	.769	.8715	.3764	.706	.8729	.3798	.701	.7510	.2872	.599
5983.6060	.9485	-.582	.8729	.3798	.701	.8743	.3832	.696	.7524	.2906	.592
.6074	.9510	.557	.8743	.3832	.696	.8757	.3866	.691	.7538	.2940	.591
.6088	.9553	.506	.8757	.3866	.691	.8771	.3900	.686	.7552	.2974	.572
.7001	.9587	.504	.8771	.3900	.686	.8785	.3934	.681	.7566	.3008	.511
.7064	.9739	.469	.8785	.3934	.681	.8799	.3968	.676	.7580	.3042	.520
.7078	.9773	.448	.8799	.3968	.676	.8813	.4002	.671	.7594	.3076	.524
.7092	.9807	.457	.8813	.4002	.671	.8827	.4036	.666	.7608	.3110	.487
.7105	.9841	.445	.8827	.4036	.666	.8841	.4070	.661	.7622	.3144	.495
.7161	.9976	.470	.8841	.4070	.661	.8855	.4104	.656	.7636	.3178	.485
.7175	.0010	.470	.8855	.4104	.656	.8869	.4138	.651	.7650	.3212	.466
.7190	.0047	.452	.8869	.4138	.651	.8883	.4172	.646	.7664	.3246	.478
.7203	.0078	.464	.8883	.4172	.646	.8897	.4206	.641	.7678	.3280	.494
.7258	.0214	.478	.8897	.4206	.641	.8911	.4240	.636	.7692	.3314	.492
.7272	.0248	.494	.8911	.4240	.636	.8925	.4274	.631	.7706	.3348	.495
.7286	.0282	.504	.8925	.4274	.631	.8939	.4308	.626	.7720	.3382	.485
.7300	.0315	.490	.8939	.4308	.626	.8953	.4342	.621	.7734	.3416	.470
.7356	.0451	.523	.8953	.4342	.621	.8967	.4376	.616	.7748	.3450	.474
.7370	.0485	.548	.8967	.4376	.616	.8981	.4410	.611	.7762	.3484	.474
.7385	.0522	.577	.8981	.4410	.611	.8995	.4444	.606	.7776	.3518	.474
.7397	.0553	.580	.8995	.4444	.606	.9009	.4478	.601	.7790	.3552	.470
.7460	.0705	.625	.9009	.4478	.601	.9023	.4512	.596	.7804	.3586	.470
.7474	.0739	.655	.9023	.4512	.596	.9037	.4546	.591	.7818	.3620	.474
.7488	.0773	.662	.9037	.4546	.591	.9051	.4580	.586	.7832	.3654	.474
.7503	.0810	.694	.9051	.4580	.586	.9065	.4614	.581	.7846	.3688	.474
.7613	.1078	-.770	.9065	.4614	.581	.9079	.4648	.576	.7860	.3722	.474

AB Andromedae. This system was discovered by P. Guthnick and R. Prager (1927). The variable was observed photoelectrically during the fall and winter of 1957 during nine nights. The same instruments were used and the same technique was followed as before. A total of 391 yellow and 390 blue magnitudes was obtained.

Table V gives the information about the BD numbers and position of the stars. The spectrum of AB Andromedae is that given by O. Struve and collaborators (1950), who give the radial velocities.

No correction for differential extinction was necessary. Times of minima were then computed and are listed in Table VI. In addition normal points of earlier observations are given; the $O-C$ are computed with Oosterhoff's (1950) formula, who made many accurate photographic determinations of the minima times.

$$\text{Min. I} = 2425502.11989 + 0.331886486 E$$

Our observed minima occur about 50 minutes later than expected from this ephemeris and confirm the recent visually observed times of minima of this system. (See Figure 2.) The new formula used for determining the phases is:

$$\text{Min. I} = 2436109.57835 + 0.33188940 E$$

TABLE VI. TIMES OF MINIMA AND RESIDUALS OF AB ANDROMEDAE

J. D. $\odot$.	Min.	O-C	Meth.	Obs.	Ref.
2416103.925	II	+ ^d .000	pg	He	1
8684.512	I	.004	pg	Sh	2
8963.633	I	.009	pg	Sh	2
24760.360	I	.006	pg	G, P	3
5276.4445	I	.0074	pg	Jo	4
5502.1267	I	.0068	pg	Oo	2
5873.5073	I	.0064	pg	Oo	2
6216.1793	II	+ .0056	pg	Oo	2
9523.583	I	-.006	pg	Wo	5
9550.6312	II	.0060	pg	Oo	2
9907.7398	II	.0072	pg	Oo	2
30257.8803	II	.0070	pg	Oo	2
0611.8379	I	.0063	pg	Oo	2
0962.645	I	-.003	pg	Wo	5
1046.615	I	.000	pg	Wo	5
1350.4580	II	+ .0004	pg	Oo	2
1707.9018	II	.0025	pg	Oo	2
2133.0469	II	.0010	pg	Oo	2
2413.1603	II	.0022	pg	Oo	2
2793.671	I	.005	pg	Wo	5
3207.3684	II	.0059	pg	Oo	2
3886.578	I	.011	v	D, J	6
4264.600	I	.013	v	As	7
5075.407	I	.021	v	Sz	8
5370.460	I	.027	v	Sz	9
5782.336	I	.033	v	Sz	10
6069.421	I	.035	v	S, G	11
6109.57835	I	.0345	pe	Bi	—
6124.68008	II	.0354	pe	Bi	—
6132.64609	II	+ .0361	pe	Bi	—

He = Hertzprung, Sh = Shapley, G, P = Guthnick and Prager, Jo = Jordan, Oo = Oosterhoff, Wo = Woodward, D, J = Domke and Jahn, As = Ashbrook, Sz = Szafraniec, S, G = Satanova and Grigorevsky, Bi = Binnendijk.
1 = Hertzprung 1928; 2 = Oosterhoff 1950; 3 = Guthnick and Prager 1927; 4 = Jordan 1929; 5 = Woodward 1951; 6 = Domke and Pohl 1952; 7 = Ashbrook 1952, 1958; 8, 9, 10 = Szafraniec 1955, 1956, 1957; 11 = Satanova and Grigorevsky 1957.

TABLE V. VARIABLE AND COMPARISON STARS				
Star	BD No.	R.A. (1900)	D. (1900)	Sp.
AB And	+36° 5017	23 ^h 6 ^m 46 ^s	+36° 21' 1	G5
comp. star	+35 4972	23 6 54	+36 7.9	—
check star	+35 4979	23 7 47	+36 8.5	—

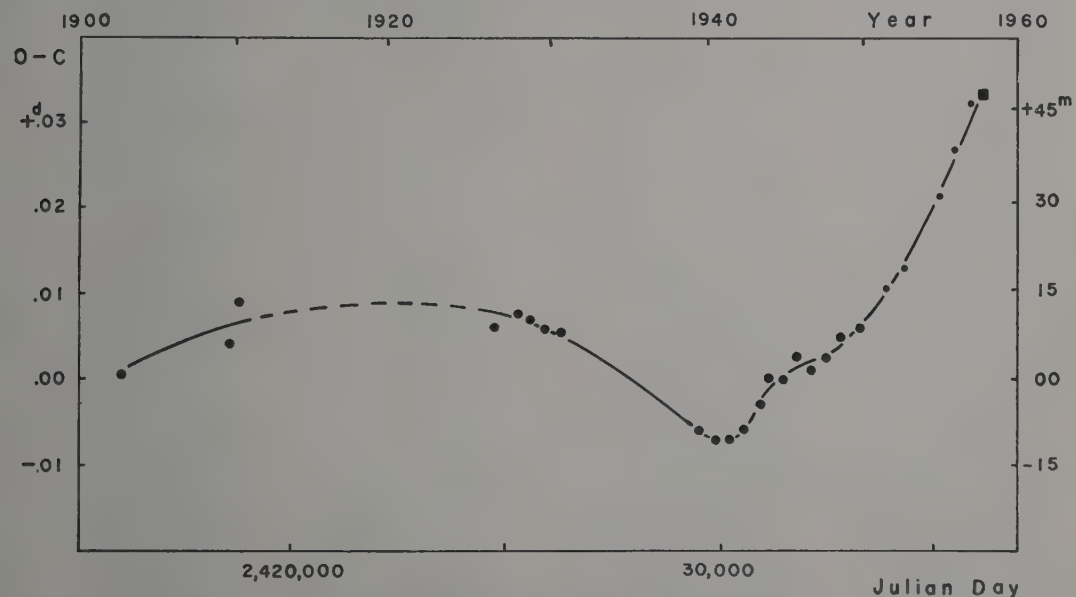


Figure 2. Period variation of AB Andromedae. Visual normal points are small dots, photographic observations large dots, photoelectric data squares.

TABLE VIIa. YELLOW OBSERVATIONS OF AB ANDROMEDAE

JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm	JD Hel. 2430000+	Phase	Δm
6109.5382	.8791	-.275	6124.5207	.0221	+.317	6125.6011	.2774	-.447	6163.5728	.6882	-.380
.5397	.8836	.272	.5207	.0403	.186	6132.5285	.1500	-.330	.5782	.7043	.410
.5412	.8882	.258	.5283	.0451	.140	.5302	.1552	.343	.5796	.7085	.410
.5426	.8923	.245	.5298	.0497	.109	.5319	.1601	.337	.5811	.7130	.417
.5487	.9108	.162	.5315	.0545	+.062	.5334	.1646	.350	.5823	.7168	.423
.5503	.9154	.143	.5371	.0716	-.076	.5455	.2012	.406	.5946	.7538	.423
.5515	.9192	.141	.5388	.0765	.092	.5471	.2061	.401	.5960	.7580	.431
.5529	.9234	-.107	.5403	.0811	.125	.5488	.2110	.398	.5974	.7622	.431
.5621	.9509	+.128	.5417	.0852	.153	.5504	.2159	.416	.5988	.7663	.444
.5636	.9555	.141	.5471	.1016	.229	.5559	.2326	.409	.6041	.7824	.430
.5650	.9596	.197	.5486	.1061	.235	.5574	.2372	.441	.6055	.7866	.425
.5665	.9642	.241	.5500	.1103	.247	.5588	.2413	.437	.6069	.7907	.428
.5719	.9806	.346	.5515	.1149	.271	.5640	.2570	.422	.6083	.7949	.424
.5737	.9861	.360	.5568	.1309	.317	.5656	.2619	.441	.6133	.8103	.403
.5753	.9907	.366	.5584	.1358	.325	.5672	.2664	.435	.6147	.8145	.413
.5768	.9952	.372	.5600	.1403	.337	.5684	.2703	.439	.6161	.8186	.405
.5828	.0134	.383	.5612	.1442	.339	.5735	.2856	.426	.6175	.8228	.413
.5844	.0182	.371	.5730	.1708	.407	.5750	.2902	.411	.6231	.8366	.398
.5858	.0224	.330	.5740	.1846	.401	.5761	.2933	.424	.6245	.8408	.386
.5872	.0266	.320	.5795	.1902	.418	.5775	.2975	.439	.6259	.8450	.386
.5941	.0475	.126	.5783	.1958	.426	.5828	.3135	.417	.6272	.8521	.363
.5957	.0524	.087	.5888	.2272	.426	.5843	.3181	.419	.6326	.8682	.346
.5973	.0569	.047	.5904	.2320	.440	.5859	.3229	.411	.6340	.8724	.339
.5990	.0622	+.018	.5933	.2407	.444	.5873	.3271	.402	.6353	.8765	.326
.6111	.0988	-.218	.5943	.2439	.449	.5925	.3428	.386	.6367	.8807	.317
.6128	.1037	.240	.6000	.2610	.435	.5941	.3477	.378	6172.5344	.6898	-.398
.6143	.1082	.260	.6015	.2655	.441	.5956	.3522	.354	.6359	.6944	.410
.6158	.1127	.272	.6031	.2704	.434	.5970	.3564	.365	.6372	.6982	.416
.6258	.1431	.336	.6049	.2757	.441	.6025	.3728	.325	.6387	.7027	.418
.6272	.1473	.340	.6120	.2973	.434	.6041	.3777	.305	.6441	.7191	.430
.6286	.1515	.358	.6134	.3015	.395	.6055	.3819	.295	.6456	.7236	.436
.6300	.1549	.340	.6102	.3098	.401	.6069	.3860	.277	.6471	.7282	.443
.6358	.1731	.373	.6251	.3367	.385	.6122	.4021	.239	.6486	.7327	.443
.6372	.1773	.386	.6267	.3416	.374	.6136	.4063	.243	.6541	.7491	.441
.6387	.1818	.401	.6283	.3464	.370	.6150	.4105	.211	.6556	.7536	.449
.6403	.1867	.402	.6399	.3813	.315	.6164	.4147	.206	.6570	.7578	.446
.6460	.2037	.433	.6415	.3862	.303	.6217	.4307	.161	.6585	.7624	.441
.6476	.2086	.436	.6429	.3904	.313	.6231	.4349	.129	.6650	.7819	.428
.6494	.2142	.436	.6448	.3959	.300	.6244	.4391	.118	.6665	.7864	.440
.6510	.2187	.436	.6517	.4169	.208	.6261	.4440	-.060	.6678	.7906	.434
.6567	.2362	.440	.6535	.4221	.197	.6318	.4614	+.046	.6692	.7948	.426
.6584	.2410	.449	.6549	.4263	.160	.6335	.4663	.069	.6748	.8115	.412
.6601	.2463	.449	.6564	.4308	-.128	.6351	.4712	.095	.6762	.8157	.411
.6661	.2645	.451	.6631	.4511	.000	.6406	.4879	.190	.6774	.8196	.405
.6676	.2690	.445	.6647	.4559	+.021	.6422	.4924	.201	.6788	.8237	.391
.6691	.2735	.452	.6663	.4608	.062	.6435	.4966	.217	.6803	.8283	.382
.6705	.2777	.455	.6677	.4650	.082	.6452	.5015	.228	.6859	.8450	.362
.6772	.2979	.413	.6700	.4901	.195	.6511	.5193	.179	.6873	.8492	.351
.6787	.3025	.420	.6774	.4943	.210	.6526	.5238	.180	.6887	.8534	.342
.6800	.3063	.414	.6780	.4988	.212	.6539	.5277	.162	.6900	.8572	.340
.6817	.3115	.421	.6804	.5034	.223	.6555	.5326	.123	.6957	.8747	.291
.6876	.3293	.394	.6869	.5229	.154	.6613	.5500	.027	.6974	.8795	.288
.6893	.3342	.388	.6885	.5278	.130	.6626	.5541	+.009	.6986	.8834	.285
.6906	.3384	.386	.6899	.5320	.096	.6643	.5590	-.035	.6991	.8879	.271
.6921	.3429	.383	.6913	.5361	+.106	.6658	.5636	.084	.6959	.9053	.195
.7030	.3774	.395	.6964	.5515	-.021	.6710	.5793	.137	.6974	.9098	.174
.7051	.3819	.387	.6978	.5557	.054	.6726	.5842	.162	.6988	.9140	.141
.7066	.3865	.287	.6994	.5606	.069	.6741	.5887	.187	.6993	.9186	-.114
.7083	.3917	.288	.7010	.5653	.083	.6755	.5929	.195	.6999	.9233	+.024
.7140	.4088	.221	.7076	.5853	.158	.6809	.6093	.225	.6999	.9309	.048
.7154	.4130	.197	.7089	.5892	.184	.6828	.6148	.250	.6999	.9444	.072
.7168	.4172	.186	.7105	.5941	.196	.6842	.6190	.244	.6999	.9493	+.096
.7182	.4214	.165	.7123	.5993	.205	.6859	.6243	.260	6174.5342	.7155	-.413
.7240	.4388	.086	.7240	.6373	.288	.6913	.6407	.293	.5370	.7239	.424
.7256	.4437	.030	.7279	.6463	.292	.6927	.6449	.289	.5385	.7284	.432
.7271	.4482	-.011	.7293	.6505	.328	.6941	.6490	.314	.5440	.7448	.441
.7287	.4531	+.026	.7346	.6666	.349	.6955	.6532	.316	.5454	.7490	.450
.7302	.4576	.033	.7301	.6711	.360	.7069	.6874	.363	.5409	.7535	.455
.7301	.4754	.149	.7375	.6753	.357	.7084	.6919	.376	.5483	.7577	.458
.7377	.4803	.174	.7391	.6802	-.388	.7099	.6964	.387	.5537	.7741	.435
.7393	.4848	.187	6125.5186	.0288	+.276	.7111	.7003	.391	.5551	.7783	.439
.7457	.5044	.232	.5200	.0330	.232	6155.5777	.5985	-.219	.5565	.7825	.434
.7471	.5085	.215	.5215	.0375	.202	.5701	.7207	.228	.5580	.7870	.431
.7489	.5138	.217	.5229	.0417	.156	.5805	.6069	.249	.5634	.8034	.416
.7502	.5179	.199	.5283	.0581	.037	.5819	.6110	.268	.5655	.8097	.419
6115.5556	.0066	+.367	.5299	.0630	+.004	.6035	.6762	.370	.5669	.8139	.416
.5571	.0142	.388	.5334	.0735	-.080	.6050	.6808	.379	.5683	.8180	.407
.5653	.0390	.214	.5349	.0780	.108	.6064	.6850	.374	.5738	.8348	.389
.5669	.0438	+.188	.5402	.0940	.204	.6077	.6888	.381	.5752	.8390	.375
.5745	.0668	-.013	.5416	.0982	.220	.6130	.7048	.397	.5767	.8435	.397
.5759	.0710	.055	.5431	.1027	.236	.6145	.7094	.407	.5781	.8477	.345
.5814	.0874	.143	.5446	.1073	.254	.6159	.7136	.416	.5808	.8829	.281
.5830	.0923	.174	.5503	.1244	.312	.6172	.7174	.430	.5914	.8878	.262
.5903	.1143	.244	.5519	.1293	.318	.6227	.7341	.450	.5929	.8923	.259
.5918	.1188	.275	.5552	.1390	.361	.6241	.7383	.467	.5943	.8965	.244
.6028	.1510	.352	.5613	.1575	.369	.6256	.7428	.448	.5998	.9129	.158
.6044	.1568	.431	.5631	.1627	.357	.6269	.7467	.462	.6013	.9174	.139
.6220	.2098	.426	.5648	.1680	.364	6103.5405	.6178	-.254	.6027	.9210	.103
.6235	.2143	.412	.5666	.1736	.385	.5309	.6220	.258	.6040	.9258	-.010
.6314	.2381	.446	.5783	.2088	.403	.5324	.6265	.287	.6095	.9422	+.094
.6328	.2422	.444	.5797	.2130	.402	.5330	.6303	.292	.6110	.9467	.050
.6384	.2594	.443	.5813	.2178	.422	.5390	.6464	.338	.6124	.9509	.089
.6400	.2642	.447	.5830	.2227	.451	.5603	.6506	.341	.6139	.9554	.126
.6458	.2817	.430	.5885	.2394	.459	.5618	.6551	.339	.6194	.9722	.269
.6477	.2872	.424	.5901	.2443	.442	.5631	.6589	.338	.6211	.9771	.325
6124.5101	.0082	+.346	.5915	.2485	.454	.5687	.6757	.375	.6226	.9816	.353
.5177	.0130	.340	.5930	.2530	.447	.5701	.6798	.386	.6240	.9858	+.371
.5193	.0179	+.355	.5994	.2722	-.439	.5714	.6840	-.388			

TABLE VIIb. BLUE OBSERVATIONS OF AB ANDROMEDAE

JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm	JD Hel. 2430000 +	Phase	Δm
6109.5300	.8815	-.240	6124.5274	.0423	+.242	6125.6003	.2750	-.437	6163.5735	.6903	-.367
.5403	.8854	.231	.5200	.0472	.179	.6017	.2792	-.425	.5789	.7063	.389
.5419	.8903	.218	.5304	.0514	.160	6132.5203	.1524	-.305	.5803	.7105	.381
.5433	.8945	.108	.5323	.0570	+.098	.5309	.1573	.322	.5816	.7147	.389
.5495	.9129	.105	.5378	.0737	-.039	.5325	.1622	.316	.5830	.7189	.383
.5508	.9171	.097	.5395	.0786	.064	.5339	.1664	.329	.5953	.7559	.415
.5521	.9209	.089	.5410	.0831	.086	.5402	.2034	.364	.5967	.7601	.417
.5536	.9255	-.048	.5422	.0870	.121	.5478	.2082	.373	.5981	.7643	.417
.5629	.9534	+.200	.5478	.1037	.197	.5495	.2131	.386	.5995	.7684	.421
.5643	.9575	.229	.5492	.1079	.203	.5511	.2180	.399	.6048	.7845	.403
.5650	.9617	.271	.5507	.1124	.225	.5566	.2347	.405	.6062	.7887	.381
.5670	.9659	.301	.5522	.1170	.253	.5580	.2389	.435	.6076	.7928	.393
.5728	.9833	.407	.5575	.1330	.289	.5594	.2431	.417	.6089	.7970	.389
.5742	.9875	.434	.5591	.1379	.303	.5647	.2591	.415	.6140	.8124	.302
.5759	.9928	.430	.5605	.1421	.312	.5663	.2640	.435	.6154	.8165	.362
.5775	.9973	.442	.5619	.1463	.321	.5677	.2682	.414	.6168	.8207	.363
.5835	.0155	.432	.5737	.1818	.308	.5691	.2724	.429	.6182	.8249	.356
.5850	.0200	.416	.5756	.1874	.397	.5742	.2877	.403	.6238	.8417	.358
.5864	.0242	.396	.5773	.1927	.413	.5768	.2954	.385	.6252	.8459	.348
.5879	.0287	.362	.5790	.1978	.417	.5782	.2996	.391	.6265	.8500	.342
.5948	.0496	.147	.5805	.2293	.418	.5835	.3156	.378	.6279	.8542	.313
.5964	.0545	.118	.5911	.2341	.437	.5851	.3205	.380	.6333	.8703	.295
.5979	.0590	.083	.5938	.2425	.423	.5866	.3250	.362	.6346	.8744	.295
.5996	.0639	+.056	.5950	.2460	.437	.5879	.3289	.362	.6360	.8786	.275
.6119	.1012	-.208	.6006	.2628	.421	.5932	.3449	.345	.6374	.8828	.275
.6136	.1061	.213	.6022	.2676	.419	.5948	.3498	.332	6172.5331	.6919	-.369
.6150	.1150	.234	.6037	.2722	.429	.5962	.3540	.319	.5305	.6961	.384
.6166	.1152	.430	.6054	.2761	.429	.5976	.3574	.315	.5319	.7003	.392
.6205	.1452	.310	.6109	.2941	.396	.6032	.3749	.288	.5333	.7045	.390
.6279	.1494	.335	.6126	.2990	.411	.6048	.3798	.268	.5448	.7212	.408
.6293	.1535	.342	.6141	.3036	.379	.6062	.3840	.255	.5464	.7261	.417
.6307	.1577	.339	.6169	.3170	.381	.6075	.3881	.244	.5479	.7306	.408
.6365	.1752	.357	.6258	.3388	.362	.6129	.4042	.189	.5492	.7345	.411
.6379	.1793	.303	.6274	.3436	.342	.6143	.4084	.195	.5548	.7512	.431
.6395	.1842	.378	.6290	.3485	.337	.6156	.4126	.152	.5563	.7557	.415
.6411	.1891	.381	.6406	.3834	.263	.6170	.4168	.149	.5577	.7599	.432
.6467	.2058	.406	.6422	.3883	.244	.6224	.4328	.097	.5592	.7644	.424
.6483	.2107	.417	.6436	.3925	.241	.6237	.4370	.053	.5656	.7840	.407
.6500	.2159	.422	.6455	.3981	.231	.6251	.4412	.042	.5672	.7885	.426
.6518	.2212	.435	.6524	.4190	.140	.6268	.4461	+.007	.5684	.7923	.422
.6574	.2383	.438	.6541	.4239	.135	.6325	.4639	.102	.5699	.7965	.392
.6592	.2435	.450	.6554	.4281	.097	.6342	.4683	.138	.5754	.8133	.381
.6608	.2484	.453	.6571	.4329	-.061	.6358	.4732	.158	.5767	.8174	.391
.6668	.2665	.449	.6638	.4532	+.060	.6413	.4900	.263	.5782	.8216	.386
.6684	.2714	.445	.6654	.4580	.102	.6427	.4942	.268	.5795	.8258	.377
.6696	.2749	.442	.6670	.4629	.132	.6441	.4984	.286	.5865	.8468	.326
.6713	.2801	.439	.6684	.4671	.159	.6461	.5043	.272	.5879	.8509	.327
.6779	.3000	.405	.6767	.4922	.273	.6518	.5214	.229	.5893	.8551	.320
.6793	.3042	.400	.6782	.4967	.294	.6532	.5256	.234	.5906	.8593	.320
.6808	.3087	.406	.6797	.5013	.284	.6547	.5301	.196	.5964	.8707	.246
.6825	.3140	.392	.6811	.5054	.289	.6562	.5346	.162	.5979	.8813	.238
.6886	.3321	.357	.6876	.5250	.200	.6620	.5521	.062	.5993	.8854	.236
.6899	.3363	.357	.6892	.5298	.182	.6633	.5563	+.023	.6008	.8896	.217
.6913	.3404	.348	.6906	.5340	.159	.6650	.5612	-.004	.6066	.9012	.136
.6928	.3450	.435	.6971	.5536	+.000	.6663	.5653	.040	.6080	.9116	.119
.7043	.3795	.238	.6985	.5578	.000	.6717	.5814	.112	.6094	.9158	.099
.7058	.3840	.255	.7001	.5627	-.023	.6733	.5862	.121	.6110	.9207	-.063
.7074	.3889	.242	.7022	.5680	.061	.6747	.5904	.151	.6166	.9374	+.088
.7092	.3941	.226	.7082	.5871	.150	.6761	.5946	.151	.6181	.9419	.098
.7147	.4109	.152	.7096	.5973	.174	.6816	.6113	.183	.6196	.9465	.146
.7161	.4151	.138	.7112	.5961	.163	.6835	.6170	.205	.6213	.9517	+.159
.7175	.4193	.135	.7131	.6017	.180	.6851	.6218	.217	6174.5330	.7176	-.398
.7189	.4235	.110	.7256	.6394	.276	.6867	.6267	.230	.5303	.7218	.398
.7247	.4409	-.027	.7270	.6436	.279	.6920	.6427	.255	.5378	.7263	.416
.7263	.4458	+.021	.7286	.6484	.302	.6934	.6469	.262	.5391	.7302	.416
.7278	.4503	.041	.7300	.6520	.303	.6948	.6511	.285	.5447	.7469	.429
.7293	.4555	.075	.7353	.6687	.329	.6962	.6553	.292	.5461	.7511	.433
.7309	.4597	.084	.7367	.6728	.344	.7076	.6895	.357	.5475	.7553	.437
.7369	.4778	.206	.7383	.6777	.330	.7092	.6944	.359	.5490	.7598	.439
.7386	.4827	.238	.7398	.6822	-.356	.7104	.6982	.372	.5544	.7762	.428
.7401	.4873	.263	6125.5193	.0309	+.321	.7117	.7020	.368	.5558	.7804	.422
.7464	.5064	.293	.5207	.0351	.267	6155.5784	.6006	-.183	.5572	.7846	.426
.7480	.5113	.284	.5221	.0393	.237	.5798	.6048	.203	.5586	.7888	.404
.7496	.5159	.280	.5235	.0435	.188	.5812	.6090	.196	.5648	.8076	.370
6115.5503	.0117	+.440	.5290	.0602	.065	.5826	.6131	.233	.5662	.8117	.366
.5576	.0159	.440	.5306	.0651	+.032	.6042	.6784	.359	.5676	.8159	.350
.5600	.0410	.280	.5341	.0756	-.043	.6056	.6824	.357	.5690	.8201	.357
.5676	.0459	.232	.5355	.0798	.059	.6070	.6867	.304	.5745	.8368	.346
.5753	.0693	+.053	.5410	.0961	.180	.6084	.6906	.343	.5759	.8410	.340
.5766	.0731	-.008	.5422	.1000	.203	.6137	.7070	.378	.5773	.8453	.331
.5819	.0862	.109	.5438	.1049	.208	.6152	.7115	.393	.5787	.8494	.310
.5836	.0940	.133	.5452	.1090	.222	.6166	.7157	.386	.5905	.8850	.239
.5910	.1164	.225	.5510	.1265	.291	.6179	.7195	.407	.5921	.8890	.212
.5924	.1206	.251	.5525	.1310	.303	.6234	.7362	.437	.5936	.8944	.223
.6035	.1540	.322	.5541	.1359	.306	.6248	.7404	.437	.5950	.8986	.194
.6051	.1589	.339	.5559	.1411	.328	.6262	.7446	.437	.6005	.9150	.111
.6227	.2179	.402	.5621	.1600	.335	.6277	.7491	.415	.6018	.9192	.086
.6250	.2189	.389	.5638	.1648	.340	6163.5502	.6199	-.232	.6032	.9234	.048
.6319	.2398	.414	.5656	.1674	.333	.5516	.6241	.242	.6046	.9275	-.031
.6336	.2447	.404	.5676	.1703	.352	.5529	.6283	.249	.6102	.9443	+.083
.6391	.2614	.405	.5799	.2108	.386	.5543	.6324	.277	.6116	.9485	.133
.6407	.2663	.416	.5804	.2150	.394	.5596	.6485	.314	.6131	.9530	.186
.6465	.2837	-.403	.5820	.2199	.408	.5610	.6527	.314	.6147	.9579	.224
.6484	.2893	-.412	.5837	.2248	.438	.5625	.6572	.308	.6201	.9743	.363
6124.5168	.0103	+.403	.5892	.2415	.435	.5638	.6610	.308	.6218	.9792	.432
.5184	.0152	.397	.5908	.2464	.438	.5694	.6778	.355	.6231	.9833	.427
.5200	.0200	.415	.5922	.2506	.419	.5708	.6819	.368	.6245	.9875	+.403
.5214	.0242	+.391	.5937	.2551	-.444	.5722	.6861	-.364			

Table VII gives the observations, namely heliocentric Julian Day, phase counted from primary minimum, and magnitude difference. Table VIII and Figure 3 give the normal points after adding .443 to the yellow and .430 to the blue magnitudes to make the magnitude difference zero at maximum. The color shows a reddening during both minima, where again the difference of blue and yellow magnitude was considered at the same phase.

The intensity and phase angle of the normal points were computed next. Again it was found that the light in the maxima shows a reflection effect ($\cos \theta$ term) which has a sign opposite from that expected by the theory. Under these circumstances no effort was made to determine the orbital elements.

I am much indebted to Dr. R. S. Alexander who spent three nights observing V566 Ophiuchi, and to Mr. H. G. Haynes, Jr. who observed AB Andromedae during three nights. Part of this work was supported by the ONR contract Nonr 2320(00).

REFERENCES

V566 Ophiuchi

- Fresa, A. 1954, *Mem. Soc. Astr. Ital.* **25**, No. 2; *Contr. Astr. Napoli (Capodimonte)*, Serie II, **4**, No. 14.
 Hertzsprung, E. 1928, *B. A. N.* **4**, 179.
 Hoffmeister, C. 1935, *A. N.* **255**, 401.
 —. 1943, *Kleinere Veröff. Berlin-Babelsberg* No. 28, 81.
 Kwee, K. K. 1958, *B. A. N.* **14**, 131.
 Roman, N. G. 1956, *Ap. J.* **123**, 246.
 Tsesevich, V. P. 1950, *Astr. Circ. U.S.S.R.* No. 100, 18.
 —. 1954, *Izvestia Astr. Obs. Odessa* **4**, Part II, 236.

AB Andromedae

- Ashbrook, J. 1952, *A. J.* **57**, 259.
 —. 1958, *A. J.* **58**, 171.
 Domke, K. and Pohl, E. 1952, *A. N.* **281**, 113.
 Guthnick, P. and Prager, R. 1927, *A. N.* **229**, 455.
 —. 1927, *Kleinere Veröff. Berlin-Babelsberg* No. 4, 16.
 Hertzsprung, E. 1928, *B. A. N.* **4**, 153.
 Jordan, F. C. 1929, *Pub. Allegheny Obs.* **7**, 136.
 Oosterhoff, P. Th. 1929, *B. A. N.* **5**, 37.
 —. 1930, *B. A. N.* **5**, 151.
 —. 1950, *B. A. N.* **11**, 217.
 Satanova, E. A. and Grigorevsky, V. M. 1957, *Astr. Circ. U.S.S.R.* No. 187, 17.
 Struve, O., Horak, H. G., Canavaggia, R., Kourganoff, V. and Colacevich, A. 1950, *Ap. J.* **111**, 658; *Contr. McDonald Obs.* No. 189.
 Szafraniec, R. 1955, *Acta Astr.* Ser. c, **5**, 193.
 —. 1956, *Acta Astr.* **6**, 141.
 —. 1957, *Acta Astr.* **7**, 188.
 —. 1958, *Roczn. Astr. Obs. Krakow* No. 29, 106.
 Woodward, E. J. 1951, *A. J.* **56**, 77.

ERRATA

A. J. 63, No. 1259:

Page 164, in appendix table, line Perth: *for* incomplete *read* complete.

in note to table, under *Zones missing*: delete -32° to -37° .

Mr. Spigl from Perth Observatory (Western Australia) kindly called the author's attention to the omission of the relevant volumes of the Astrographic Catalogue published in Perth as early as 1922. Due to the circumstances at the end of the first world war these volumes never reached the Hamburg Observatory.

A. J. 63, No. 1264:

Page 431, line 2, *for* $\sin \eta$ *read* $\sin \eta'$.

line 11-12, the formula for $(r\partial\Omega/\partial r)^*$ needs a factor $(a/r)^5$ associated with the factor $-5k_4$.

line 19, *for* $\partial\Omega/\partial E = (\partial\Omega/\partial E)^*$ *read* $\partial\Omega/\partial E = (\partial\Omega/\partial E')^*$.

A. J. 63, No. 1264:

Page 462, lines 36-44, in Sterne's remarks: *for* Thus . . . density. *read* Thus, he proposed to carry out a broad step-by-step numerical integration in which the satellite travels through an osculating exponential atmosphere adjusted to the density and density gradient at perigee. Each step consists of several hundred revolutions. Because the orbit is changing and the perigee has changed its position, it will be desirable to restart the procedure with new perigeeal values.

CONSTITUTION OF THE AMERICAN ASTRONOMICAL SOCIETY

Adopted September 1899; Amended December 1906, August 1912, August 1914, August 1915, September 1919, August 1929, September 1930, December 1947, June 1949, December 1949, December 1950, December 1951.

ARTICLE I—NAME AND PURPOSE

1. This Association shall be called the American Astronomical Society.
2. The purpose of this Society is the advancement of astronomy and closely related branches of science.

ARTICLE II—MEMBERSHIP

1. Those persons whose names were signed on or before September 15, 1899, to the statement of desire to form such an association shall constitute the charter members of this Society. The charter members, together with such other persons as may be elected by the Council hereinafter provided, shall constitute the members of the Society.
2. Upon nomination by not less than five members, the Council may elect to honorary membership one astronomer of distinction at each annual meeting. American astronomers shall not be eligible to honorary membership. Honorary members shall be exempt from dues or assessments, and shall be entitled to all the privileges of the Society.
3. Any person who has rendered conspicuous service to astronomy otherwise than through scientific contributions may be elected by the Council to be a patron of the Society.
4. The Council shall prepare and publish in the form of by-laws uniform rules for the election of members.

ARTICLE III—OFFICERS AND COUNCIL

(Amended March 1956)

1. The officers of the Society shall consist of a president, president-elect, two vice-presidents, a secretary, and a treasurer, who in addition to the duties specifically assigned to them by this Constitution shall discharge the other duties usually incident to their respective offices.
2. The Council shall consist of the officers, the two available ex-presidents whose presidential terms have most recently expired, provided they have served their full terms, and of nine councillors elected from the membership of the Society. The management of all affairs of the Society not otherwise provided for shall be entrusted to the Council. The president and the secretary of the Society shall serve respectively as chairman and secretary of the Council. Each officer of the Society shall be responsible to the Council and shall administer his office in accordance with its instructions.
3. The word "Council" as herein used and the word "Directors" as used in the Articles of Incorporation shall be held to mean one and the same thing, and the Council shall exercise all of the functions of the Directors and the Directors shall exercise all of the functions of the Council.
4. The term of office shall be two years for the president with one additional year as president-elect, two years for the vice-presidents, three years for the secretary, three years for the treasurer, and three years for each of the nine councillors. The president-elect, who shall assume the office of president immediately after a regular annual meeting, shall be chosen as president-elect at the preceding annual meeting. The president-elect shall be nominated only from among those members of the Society who have served at least one year on the Council. The president, vice-presidents, and nine councillors shall not be eligible for immediate re-election.
5. If the president of the Society should die or resign before the expiration of his term of office, the president-elect shall act as president for the remainder of the unexpired term and shall then continue to serve the term for which he was originally elected. If no president-elect exists, the senior vice-president shall act as president until the next annual meeting, when a president shall be elected by the Society. Vacancies which may exist at any time in the offices of secretary or treasurer may be filled temporarily by the Council. If a vice-president or a councillor should die or resign more than one year before the expiration of his term, the vacancy for the unexpired term shall be filled by the Society at the next annual meeting.

ARTICLE IV—AMENDMENTS

This Constitution shall not be amended unless notice of the proposed amendment be sent by mail to every member of the Society at least one month in advance of the meeting at which such amendment is to be considered; such amendment in order to be adopted must receive three-fourths of the votes cast in person and by mail.

BY-LAWS

ARTICLE I—ELECTION OF MEMBERS

Any person deemed capable of preparing an acceptable paper upon some subject of astronomy or related branch of science may be elected by the Council to membership in the Society upon nomination by two or more members of the Society. At least once each year the Council shall consider all such nominations. Election to membership may be made by circulation of a nomination to the members of the Council through the mail, but one vote to disapprove or two votes to defer shall cause the application to be referred to the next meeting of the Council. Blanks for nomination to membership shall be furnished by the secretary.

ARTICLE II—DUTIES OF OFFICERS AND MEMBERS OF THE COUNCIL

(Amended December 1949, March 1956)

1. Members elected to offices in the Society shall be notified of such election in writing by the secretary within ten days thereafter. It shall be the duty of each person thus notified to file with the secretary his written acceptance of such office, and if such acceptance is not filed within sixty days after the notification, the Council by resolution may declare such office vacant and may elect any other member of the Society to fill it until the election at the next annual meeting.

2. It shall be the duty of the president to deliver an address before the Society at the meeting next after that in which his term of office expires.

3. The president, the secretary, the treasurer, and the ex-president most recently in office shall constitute an executive committee of the Council to act *ad interim* upon all such minor matters affecting the Society as in their judgment do not call for submission to the entire Council. Such actions of the executive committee shall be reported to the Council at its next subsequent meeting. The president-elect shall also be a member, without vote, of the executive committee.

4. The secretary shall be the purchasing officer of the Society, and the treasurer shall be the disbursing officer and shall pay out monies only in accordance with a budget approved by the Council. Emergency expenditures not covered by the *approved budget* shall require interim approval of the executive committee, and shall be reported to the Council at the next meeting of the Society.

5. The treasurer shall keep accounts showing all receipts and expenditures of monies belonging to the Society, and showing also the indebtedness to the Society of each member thereof on account of dues. The secretary shall keep accounts showing the financial transactions of his office. The accounts of the treasurer and of the secretary shall be audited by a committee of not less than two members before being submitted to the Council at each annual meeting.

ARTICLE III—FINANCE

(Amended December 1939, June 1949, December 1951, August 1953, March 1956, December 1958)

1. The dues shall be five dollars a year. The amount received as dues together with the interest from the life-membership fund shall be disbursed as the Council may direct to meet the necessary expenses of the Society.

2. If the dues of any member remain unpaid after two years, the Council, after due notice, shall remove his name from the membership list.

3. Any member of the Society on retiring from his academic or other duties may, if he so requests in writing, elect to be transferred to the status of emeritus member. Emeritus members shall be exempt from payment of dues. They may not hold office in the Society, nor vote at meetings, but shall have all the other privileges of membership.

4. All members shall be required to pay the annual dues of five dollars, except as otherwise provided by the Constitution or by specific action of the Council of the Society. All members shall subscribe to the *Astrophysical Journal* or the *Astronomical Journal*, either or both of which may be selected at the reduced rate to members of the Society. The following may be exempted from subscriptions to a Journal: patrons, life members, honorary members, those under twenty-seven years of age, and those who have reached academic retirement.

5. Corporate memberships are open, upon application to and approval by the Council, to organizations whose activities are related to the field of Astronomy. Two types of corporate memberships are available:

(1) Regular corporate membership: annual dues, \$100.00.

(2) Sustaining corporate membership: annual dues, \$500.00 or more.

Corporate members shall receive the Journals without further cost, shall have the right to advertise the fact of such membership, and with Council approval to hold exhibits during meeting periods.

ARTICLE IV—MEETINGS OF THE SOCIETY

1. The Council shall determine the time and place of each meeting of the Society, and shall provide for an annual meeting at which officers shall be elected.

2. The Council shall have charge of the program for each meeting, and from the list of papers offered by members, the Council shall select those to be presented before the Society.

3. At meetings of the Society, regularly called, twenty members shall constitute a quorum.

ARTICLE V—MEETINGS OF THE COUNCIL

(Amended March 1956)

1. There shall be a meeting of the Council at the time and place of each meeting of the Society, except when specifically cancelled by vote of the Council at the previous meeting.

2. The president shall convoke the Council in special meeting whenever the affairs of the Society require it.

3. A request in writing from four members of the Council shall render the convocation of the Council obligatory.

4. At any regularly called meeting of the Council, four members shall constitute a quorum. The president or senior officer present may invite other members of the Society to sit with the Council, but any action taken by fewer than four regular members shall be subject to ratification by a majority vote of the entire Council taken by mail.

ARTICLE VI—COMMITTEES

(Amended August 1957)

The officers and councillors shall be elected by ballot at the annual meeting. The official ballot shall be prepared by a nominating committee of three members of the Society. Election, organization, and duties of this nominating committee shall be as follows: at each annual meeting of the Society, the members of the Society present shall nominate and, by ballot, elect for a term of three years one member of the committee. The chairman of the committee shall be that member whose term of office next expires. The committee shall prepare and submit to the Council a ballot containing one or two names for each vacancy, with blank spaces in which the voter may substitute other names. After approval by the Council, the ballot shall be declared official and shall be sent to each member of the Society at least one month prior to the annual meeting. Each legally voted ballot returned to the secretary in a properly sealed and signed envelope shall be counted at the annual meeting. A majority of all votes cast in person or by mail shall be necessary for election. In case of failure to secure a majority for any office, the members present at the annual meeting shall choose by ballot between the two having the highest number of votes, or, in the case of councillors, among the six having the highest number of votes.

The terms of office of all committees appointed or elected by the Society or by the Council shall end at the annual meeting next following the appointment unless otherwise specified by the Constitution or By-laws, by the Society, or by the Council.

ARTICLE VII—ASTRONOMICAL AND ASTROPHYSICAL JOURNALS

(Amended December 1951, August 1953)

1. There shall be an editorial board of the *Astronomical Journal*, consisting of an Editor and three Associate Editors appointed by the Council, and one of the Directors of the Gould Fund of the National Academy of Sciences appointed by those Directors. The duties of this Board shall be to govern the policies of the Journal.

2. The term of the Editor shall be three years, subject to renewal dating from the annual meeting. The three Associate Editors shall be appointed in rotation for terms of three years each, subject to renewal, also dating from annual meetings.

3. The Editor shall have the right to attend meetings of the Council, but not to vote.

4. The members in good standing of the Society shall be given the privilege of subscribing to the *Astronomical Journal* at a price thirty per cent below the regular subscription price, with the understanding that this discount applies only to personal subscriptions and not to those by institutions.

5. In accordance with the agreement with the University of Chicago, the editorial policy of the *Astrophysical Journal* shall be determined by an editorial board of seven members. The Managing Editor and the Associate Editor shall be members of the faculty of the University of Chicago and shall be appointed in accordance with their statutes. The five other members will normally serve for a period of five years with one vacancy occurring annually.

Eight months before the scheduled retirement of a member of the editorial board (other than the Managing Editor or Associate Editor), or whenever such a position is, or shortly will be, vacant for some other reason, the University of Chicago shall submit to the Council of the American Astronomical Society the names of three (3) Society members as nominees for this position, and the Council of the Society shall then select one of these nominees for the position.

The Managing Editor of the *Astrophysical Journal* shall have the right to attend meetings of the Council, but not to vote.

ARTICLE VIII—AMENDMENTS

These By-laws may be amended only upon recommendation of the Council and by a two-thirds vote of the members present at a meeting of the Society, provided that notice of such proposed action and of its general nature shall have been given in the call for such meeting. The Council may at any time suspend a By-law until the next meeting of the Society.

 RULES

RULES FOR THE ANNIE J. CANNON PRIZE IN ASTRONOMY

1. The Annie J. Cannon Prize is to be awarded every three years to women for distinguished contributions to astronomy or for similar contributions in related sciences which have immediate application to astronomy.

2. The prize shall be open to women of all countries.

3. The prize shall consist of a token or certificate and of a money award determined by the Council. Only the accumulated interest shall be used for the prize, the principal fund remaining intact. The American Astronomical Society shall be the custodian of the fund which shall be invested by the Treasurer of the Society on the advice of the Finance Committee.

4. The Cannon Prize Committee shall be a rotating committee of three members with one new member appointed by the Council every two years for a term of six years. Then each member will serve as Chairman during the last two years of office.

5. The Council shall consider nominations presented by the Committee and the President shall make the award at a meeting designated by the Council. However, the award may be omitted at any time at the discretion of the Council.

RULES FOR THE HELEN B. WARNER PRIZE FOR ASTRONOMY

1. The Helen B. Warner Prize is normally to be awarded annually for a significant contribution to astronomy during the five years preceding the award.

2. The recipient of the award shall be a resident of North America and under thirty-five years of age at the time of the voting of the award by the Council.
3. The prize shall be \$125.00. A travel allowance in addition may be determined by the Council.
4. The Warner Prize Committee shall be a rotating committee of three members with one new member appointed annually by the Council for a term of three years. Then each member will serve as Chairman during the last year of office.
5. The Committee will submit its nominations to the Council for approval and action.
6. The candidate receiving the prize shall be invited to present a paper on the subject for which the prize was granted at a meeting designated by the Council.

RULES FOR THE HENRY NORRIS RUSSELL LECTURESHIP

1. The Russell Lecturer is normally to be chosen annually on the basis of eminence in astronomical research.
2. The honorarium for the lecture shall be \$200.00. A travel allowance in addition may be determined by the Council.
3. The Russell Lecture Committee shall be a rotating committee of three members with one member chosen by the Council each year for a term of three years. Then each member will serve as Chairman during the last year of office.
4. The Committee will submit its nominations to the Council for approval and action.
5. The candidate selected to be the Russell Lecturer shall be invited to deliver a lecture dealing with a broad astronomical field at a meeting designated by the Council. The publication of the lecture shall be arranged as agreeable to the speaker and the Council in each case.

CONSTITUTION FOR THE UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ASTRONOMICAL UNION

Adopted by the Council of the American Astronomical Society at its meeting at Berkeley, California, August 24-28, 1956. Approved by the Governing Board of the National Academy of Sciences—National Research Council, Washington, D. C., October 14, 1956.

1. *Purpose:*

To effect appropriate United States participation in the International Astronomical Union (IAU) through the National Academy of Sciences—National Research Council, which adheres to the Union on behalf of the United States.

2. *Functions:*

- a. To advise the President of the National Academy of Sciences on all matters concerning United States participation in the Union.
- b. To promote astronomical research in the United States, with special reference to aspects that require international cooperation.
- c. To provide interim liaison between the U. S. National Committee and corresponding national committees in other countries, in such matters as planning of meetings, organizing symposia, arranging cooperative research programs, etc.
- d. To propose U. S. astronomers for membership in the IAU.
- e. To propose U. S. astronomers for membership on Commissions of the IAU.
- f. To nominate U. S. astronomers as delegates to the general assemblies of the IAU.
- g. To nominate U. S. astronomers as representatives to such IAU meetings as may occur in the interim between general assemblies.
- h. To brief delegates to general assemblies and other meetings called by the Union.
- i. To encourage cooperative international enterprises that will promote the advance of astronomical science.

j. To encourage special researches in border or crossfield sciences, such as physics, chemistry, geophysics, etc., with a view to stimulating studies that will advance the various branches of astronomy.

k. To arrange for scientific meetings in the United States in accord with the objectives of the Union.

l. To perform such other duties as are required of national committees of adhering countries under the statutes of the Union.

3. *Membership:*

a. The United States National Committee of the International Astronomical Union shall consist of the following members:

(1) *Representatives of the American Astronomical Society* (voting).

Three members, to be nominated by the American Astronomical Society.

(2) *Representatives of the Academy—Research Council* (voting).

Representatives of the AAS currently serving as members of the Division of Physical Sciences of the Academy—Research Council.

(3) *Members at Large* (voting).

Three members, to be nominated by the Council of the AAS.

(4) *Ex officio members* (voting).

(a) The President, the Immediate Past President, the Vice-Presidents, and the Secretary of the International Astronomical Union, if resident in the United States.

(b) The President and the Secretary of the American Astronomical Society.

(c) The Chairman of the Section of Astronomy of the National Academy of Sciences.

(5) *Ex officio members* (non-voting).

(a) The Chairman of the Division of Physical Sciences of the Academy—Research Council.

(b) The Director of the Office of International Relations of the Academy—Research Council.

In order to provide maximum representation on the Committee, ex officio members shall not be eligible for appointment under categories 3a(1), 3a(2), and 3a(3). An ex officio member, however, may serve under more than one ex officio category, although he shall never have more than one vote because of such an occurrence.

c. With the exception of ex officio members, the terms of appointment of members of the Committee shall be three calendar years, one member to be nominated each year, under each of the following categories: 3a(1), 3a(2), and 3a(3). Committee members may be nominated for reappointment, but continuous membership on the committee shall be limited to two consecutive terms. This provision does not apply to ex officio members. The first nominations in conformance with 3a of this constitution shall be made by November 1, 1956.

d. Nominations for membership shall be made annually by November 1, and be voted upon at the regular annual business meeting of the Society and shall be forwarded to the Division of Physical Sciences of the Academy—Research Council. Appointments shall be made by the President of the National Academy of Sciences.

e. In the event of death or resignation of a member of the Committee before expiration of his term, the President of the National Academy of Sciences shall appoint a member in replacement to serve for the unexpired portion of the term. Nomination of individuals for such appointments shall be made by the Committee chairman.

4. *Officers:*

a. Officers of the Committee shall be a Chairman, a Vice-Chairman and a Secretary (who shall be citizens of the U. S.). The Chairman and Vice-Chairman shall be appointed by the President of the National Academy of Sciences upon nomination by the Council of the American Astronomical Society and recommendation of the Division of Physical Sciences of the Academy—Research Council. The Secretary of the AAS shall also serve as secretary of the USA National Committee. The term of office of Chairman and Vice-Chairman shall be for three years, with provision for reappointment except as these terms conflict with 3c above.

b. Duties of the Chairman: The Chairman of the Committee shall perform the usual duties of a committee chairman, including specifically the following:

- (1) Calling meetings of the Committee.
- (2) Presiding over meetings of the Committee.
- (3) Serving as a member of the Committee on International Scientific Unions of the Academy—Research Council.

When an emergency requires rapid transaction of urgent business, the Chairman may act for the Committee, subject to confirmation by the following procedure: The full membership of the Committee must be notified by mail of each such action as soon as possible, and each such action must be voted upon, by letter ballot, within ten days of the mailing of the notification.

c. Duties of the Vice-Chairman: The Vice-Chairman shall act for the Chairman in his absence.

d. Duties of the Secretary: The Secretary shall:

- (1) Keep the minutes of the meetings and furnish copies to all regular and ex officio members of the Committee, members of the Council of the American Astronomical Society and the Executive Secretary of the Division of Physical Sciences of the Academy—Research Council.
- (2) Be responsible to the National Academy of Sciences—National Research Council for the annual accounting of funds of the Committee, such funds to be received and disbursed under prior authorization of the Academy—Research Council. An annual financial report should be submitted as part of the minutes of the annual meeting of the National Committee.

5. Subcommittees:

Whenever the need arises, the Committee may form *ad hoc* subcommittees to advise the parent Committee on matters relating to United States participation in the activities of the IAU. These subcommittees shall assist the parent committee to perform the functions stated in paragraph 2 above.

6. Meetings:

a. Meetings of the Committee shall be called by the Chairman, at least once a year, at times and places designated by him.

b. One meeting shall be held not less than six months prior to a general assembly of the IAU, to consider items for inclusion on the agenda of the international meeting.

c. A majority of the full voting membership shall constitute a quorum.

7. Amendments:

Subject to approval by the Governing Board of the Academy—Research Council, this constitution may be amended, upon recommendation of the Council of the AAS, by a two-thirds vote of those members present at a meeting of the Society, provided that notice of such action and of its general nature shall have been given in the call for such a meeting.

8. General Provision:

This constitution shall come into force following its acceptance by the American Astronomical Society and subsequent approval by the Governing Board of the Academy—Research Council.
